X RAYS:

THEIR ORIGIN, DOSAGE,
— AND —
PRACTICAL APPLICATION.

By

W. E. SCHALL.

B.Sc. Lond., F. Inst. P.

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PREFACE.

THIS book is the successor to "Electro Medical Instruments and their Management," which was published for the first time in 1892.

Since that time, the advent of X rays and the development both of that art and science and of electro medicine in general have made it necessary to divide the original publication in two, of which the one deals with X rays alone and the other with general electro medical work.

In this, the X-ray section, I have endeavoured to explain the physical laws, the electrical and practical part, and especially the dosage, and I trust that it will be a help to many beginners and medical students.

I wish especially to thank my father, Mr. K. Schall, for the great amount of help and advice which he has given me in the writing of this book.

W. E. SCHALL, B.Sc., Lond.

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X RAYS.

THEIR ORIGIN, DOSAGE, AND PRACTICAL APPLICATION.

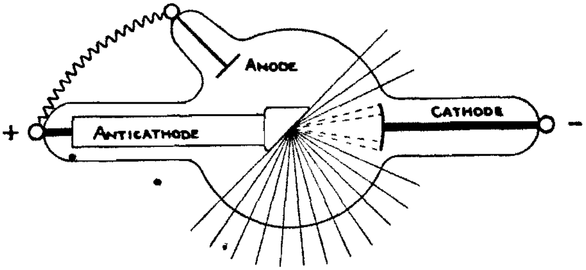


Fig. 1.

THE ORIGIN OF X RAYS, AND THEIR PROPERTIES.

To generate X rays, a glass bulb (erroneously called a tube) is necessary, which is entirely closed and into which two electrodes are sealed in such a way that they can be connected to a source of electricity outside. The latter should be capable of supplying currents with an electromotive force of not less than about 30,000 volts.

When the air in such a tube has been removed by means of an air pump, suitably connected, till the pressure inside has been reduced to about the one-hundredth part of that of the atmosphere, so that the mercury column of a barometer would have fallen from 760 mm. to about 7 mm., the phenomena well known in Geissler tubes begin to appear. When the current is turned on, it no longer discharges in the shape of yellow sparks, but bands of a bright violet colour appear between the electrodes. These bands become gradually broader, and when the pressure is further reduced to about 2 or 1 mm., the whole of the tube seems to be filled with this light. The electrical resistance becomes so low that sparks which, under normal atmospheric conditions, can overcome the resistance of an air gap no longer than 5 cm., can discharge through a distance of 100 cm. in such an evacuated tube.

When the evacuation is continued till the pressure falls to 0·02 or 0·001 mm., the violet light becomes weaker and only surrounds the electrode which is connected with the negative pole, and is called the cathode. In other parts of the tube it disappears altogether, but the glass walls of the tube begin to fluoresce and show a vivid green, blue or red colour, according to the chemicals which were used in manufacturing the glass. When, for instance, soda is present, the fluorescence is bright green. When this degree of evacuation has been reached, rays appear which start from the cathode and which are therefore called

Cathode Rays.—They were discovered by Hittorf in 1869, but were little noticed until Sir William Crookes began his interesting experiments in 1879. The cathode rays consist of unit particles of negative electricity, known as electrons, which are so small that their mass is only the $\frac{1}{1800}$ part of an atom of hydrogen. They start from the cathode perpendicularly, and in straight lines, and they attain velocities varying from $\frac{1}{3}$ to $\frac{4}{5}$ of that of light. When the cathode is given the shape of a concave mirror, the rays converge at its focus. About 99 per cent of the cathode rays are converted into heat, and thin sheets of metals of even the highest melting point, like platinum or tungsten, begin to melt when brought into this focus. The cathode rays can be deflected from their path by a magnet, but do not penetrate through the glass walls of the tube.

X rays.—While experimenting with such tubes, Röntgen found in 1895 that when these cathode rays strike a hard substance, like the glass wall of a tube, or better still a metal of high atomic weight placed at the focus of the cathode, a small percentage of them are converted into another kind of rays which, though invisible to our eyes, not only penetrate the walls of the glass, but other substances which are opaque to ordinary light, like wood, ebonite, flesh, and to a smaller degree even metals.

The "transparency" of various materials depends on their atomic weight, specific gravity and thickness. Aluminium, for instance, is about as transparent as glass, but ten times as opaque as water; lead is almost quite opaque. Flesh is more transparent than bones, the lungs filled with air are more transparent than the heart filled with blood. The transparency depends also to a large extent on the wave length of the X rays. When they enter matter, some are absorbed, their energy being devoted to produce secondary rays, chemical and biological changes, electrical and thermal effects and fluorescence. The green light of the tubes is caused by X rays which have been absorbed by the glass. Some are scattered, and finally, some will pass right through the matter. They have a great influence on cell life, and act like ordinary light on photographic plates.

X rays cannot be deflected by magnets, and have the same velocity as ordinary light, i.e., 300,000 kilometres per second.

The degree of these physical, chemical and biological effects depends on the quality and intensity of the rays which reach the object, and on the length of time they act on it.

It is of great importance that everybody who intends to use them should

ecome familiar with the meaning of the "quality" and "intensity" of X rays, and how they can be varied and measured, because the same dose will produce the same effects. We can utilize the experiences gained by others in many years of strenuous work, and by many thousands of exposures, only after we have learned to control our apparatus so that we can expose the object to the same quality and quantity.

The Nature of the X rays was for a long time a baffling secret. It was known that the cathode rays which produce them are corpuscular, that is to say, they consist of flying particles, electrons, units of negative electricity, and it became possible to measure accurately both the mass and the electrical charge of each electron. As they have a few properties in common with the cathode rays, it was thought for a while that X rays were also corpuscular, but it was gradually recognized that they must consist of a vibration of that all-pervading medium which we call ether, that they are analogous to ordinary light, and differ from it in wave length only.

This was confirmed by the experiments of Friedrich, Knipping, Laue, Sir William Bragg and his son Prof. Bragg, who, on passing X rays through crystals, found that the regularly arranged atoms of matter produce the same diffraction and interference phenomena on these rays as an ordinary diffraction grating does on visible light.

This important discovery assigned to X rays a place in the ordinary spectrum which had hitherto consisted only of the visible colours from red to violet. The only difference between X rays and visible light is therefore in their respective wave lengths.

It is interesting to note that the ether waves which are employed in wireless telegraphy are also of exactly the same nature as visible light, but the wave lengths are many million times as great.

We must therefore readjust our conception of the spectrum and enlarge it very considerably. We must realize that the spectrum consists of radiations transmitted from the ether, which differ from each other in wave length only. The longest ones, with a length of some 2 million cm. (i.e., 20 kilometres), are the wireless telegraphy waves, and the shortest, with a length of something of the order of the one-thousand millionth part of a cm., are X rays and gamma rays of radium, the latter being X rays of short wave length.

In this very extended spectrum, as we know it to-day, there is a vanishingly small part, between $\frac{1}{100000}$ and $\frac{1}{1000000}$ of a cm., in which the radiation is such that it affects the nerves in our eyes and becomes visible as that which we call light.

The illustration gives an idea as to what the spectrum must be considered to look like at present. In this figure the wave lengths of the various radiations are given in cm. As this unit is much too large, and as the infinitesimal dimensions of X and γ rays, even when expressed in millionths of a millimetre ($\mu\mu$), would require decimals, it has become customary to refer to these in terms of "Ångström" units, which are the hundred millionth part of a cm. (1×10^{-8}), denoted Å.U.; the greek letter λ is frequently

employed to denote "wave length." The wave length of the X rays use for medical purposes varies between about 1 and 0·15 Å.U. The gamma ray of radium have a λ of 0·1 Å.U. or even a little less. Violet light has a λ o 3800, green light 5000, and red light 7600 Å.U.

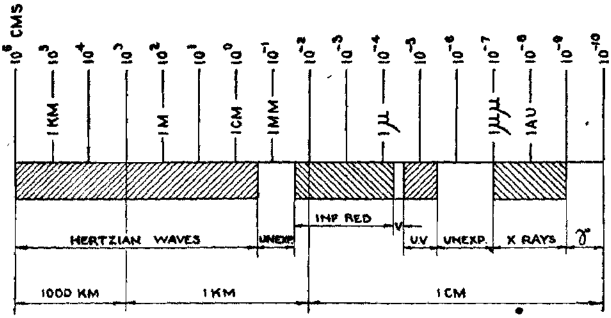


Fig. 2.

Hertzian waves	= wireless waves.	V	= visible spectrum.
Unexp. ..	= unexplored region.	U.V. ..	= ultra violet spectrum.
Inf. red ..	= infra red = heat radiation.	X	= X-rays.
		γ	= gamma rays of radium

The Quality of the X rays depends on the E.M.F., i.e., the number of volts of the current used, and on the degree of evacuation of the tube.

If we connect the electrodes of a tube during the progress of evacuation with the terminals of a transformer, for instance a spark coil, in the manner shown in the illustration, two paths are open to the discharge: one through the air gap between the electrodes of the discharging pillars of the spark coil, the other through the X-ray tube. The discharge chooses the path which offers the least resistance. The resistance between the electrodes on the discharging pillars varies with the length of the air gap, and can therefore easily be altered; the resistance of the gap between the electrodes in the tubes depends on the degree of evacuation. As long as the current prefers to discharge through the tube while the length of the air gap is only about cm., no X rays leave the tube which could be utilized for medical urposes. But when the degree of evacuation is such that the current

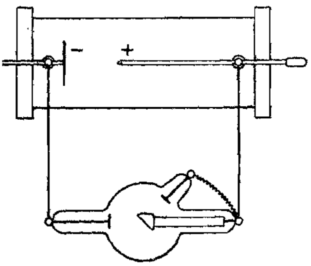


Fig. 3.

efers to discharge through an air gap 4 or 5 cm. long, so that we ust increase the distance between the point and plate on the spark il to about 5 or 6 cm. to cause the current to discharge through the tube. X rays which are useful for medical purposes begin to leave the tube.

The point at which the current just prefers to discharge through the air instead of through the tube is called the "equivalent spark gap" of the tube. When it has reached a length of about 6 cm., X rays will leave the tube which will penetrate through the flesh of the fingers. If we hold the latter between the X-ray tube and a fluorescent screen, the bones will just begin to become visible as black shadows, the flesh, the finger nails, will appear in various shades of dark grey (see *Plate I*), the parts of the screen which are not covered by the hand will fluoresce with a moderately bright light.

When the process of evacuation is continued, it becomes necessary to increase the length of the air gap to about 13 cm. to prevent the current from discharging through the air. If we examine the hand again, we find that the shadows of the flesh appear light grey, the shadows of the finger nails have disappeared, the thinner bones are no longer black, but dark grey, and begin to become transparent too; but the wrist bones are still a black mass. When the equivalent spark has reached some 20 cm., the bones of the hand appear quite light grey, and the flesh has almost ceased to give any shadow at all.

This shows that the "penetrating power" of the X rays varies widely and that it increases as the pressure of the gases left in the tube falls. A higher E.M.F. is necessary to overcome the resistance offered by a tube with an equivalent spark gap of 20 cm., than one with 5 cm. only. This higher E.M.F. causes the electrons to be propelled from the cathode with a greater velocity, and the higher this velocity, the shorter will be the wave length of the X rays which are produced when the electrons are suddenly stopped by a target of great atomic weight. The material of which the target consists has a slight influence, too, when platinum is being used, the penetrating power is about 9 per cent higher than when it consists of tungsten.

The softest rays, produced with an equivalent spark of 5 cm., will only make the outlines of the hand visible on a screen, whereas the hardest, produced in tubes with an equivalent spark of about 40 cm., will even show flaws in sheets of iron or steel 5 to 10 cm. thick. The length of the equivalent spark, and the transparency of the hand as seen on the fluorescent screen, give an approximate indication of the quality of the rays.

Up to now, the quality is described as "very soft," "soft," medium soft, medium hard, hard, very hard, etc. This is rather vague, because rays which are already too hard to produce a good negative of the kidneys, are yet too soft for many therapeutic applications. As the low or high penetrating power depends on long or short wave lengths respectively, and on that alone, just as the colours of light in the visible spectrum depend on the wave lengths, it is to be hoped that the expressions soft, hard, etc., will be replaced

gradually by the more accurate terms of the wave lengths employed. We could denote them as follows :—

	Equivalent spark.	Wave length of effective X rays in Å.U. about :
Very soft X rays ..	2 to 4 cm. ..	.. 0·8
Soft	4 ,, 9 ,, ..	.. 0·6
Medium hard	10 ,, 17 ,, ..	.. 0·45
Hard	18 ,, 25 ,, ..	.. 0·25
Very hard	26 ,, 32 ,, ..	.. 0·15
Rays for deep therapy	32 ,, 45 ,, ..	.. 0·1

That it is quite possible and easy to measure the wave lengths will be explained in the chapter describing the instruments which enable us to measure the X rays. See also pages 41–44 and page 126.

The Quantity of the X rays depends on the **number** of electrons which are propelled from the cathode in a given time. This number varies with the strength of the current, i.e., with the number of Mil. Amps. discharging through the tube. The strength of this current depends on the electromotive force prevailing on the electrodes of the tube, on the resistance of the tube, and on the frequency of the interruptions. A limit is, however, placed to the increase of the quantity by the maximum power which the electric apparatus can produce, and the maximum current which the individual tube can stand without being damaged. As the duration of the exposure depends on the quantity of the X rays available, it must be our aim to perfect tubes and apparatus so that great quantities of X rays can be produced. Instead of speaking of the quantity of X rays, the expression

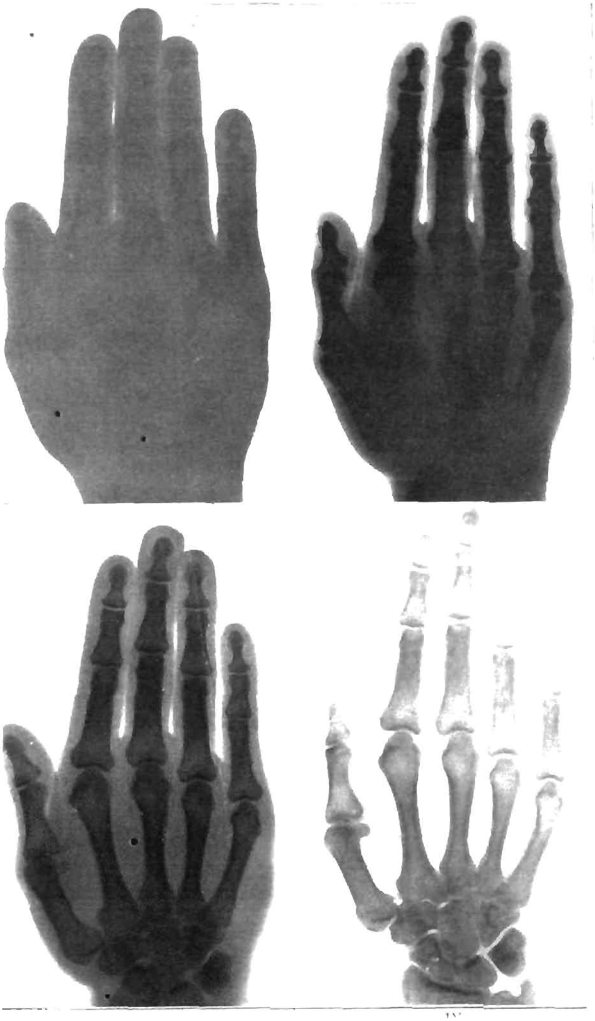
Intensity of X rays is more frequently used, and many regard this as merely another word for quantity, but this is not strictly correct. The word intensity should be applied only to the quantity of X rays traversing or available on a certain area, say a square cm., in the unit of time, a second. The intensity depends on the E.M.F. and the number of Mil. Amps. discharging through the tube, and this varies with the resistance of the tube. A current of 2 M.A. discharging through a tube with an equivalent spark of 20 cm. produces much more intense X rays than a current of the same strength discharging through a tube with an equivalent spark of 10 cm. only, because in the latter case a lower E.M.F. is sufficient to produce a current of 2 M.A. If the strength of the primary current is increased to raise the number of M.A., the E.M.F. on the terminals of the tube and the penetrating power of the rays and the intensity rise too. Moreover,

The Intensity is influenced by Distance and Absorption.—After the X rays leave the tube, their intensity diminishes rapidly. It becomes reduced as the distance between the anticathode and object increases, **and it varies inversely as the square of that distance,** like the intensity of ordinary light.

The reason for this is best explained by the well-known diagram appearing in all text-books on light. The illustration shows how the intensity of radiation coming from a point varies with the increasing distance. We consider the source of radiation to be at the point of the pyramid, and place a certain rectangular

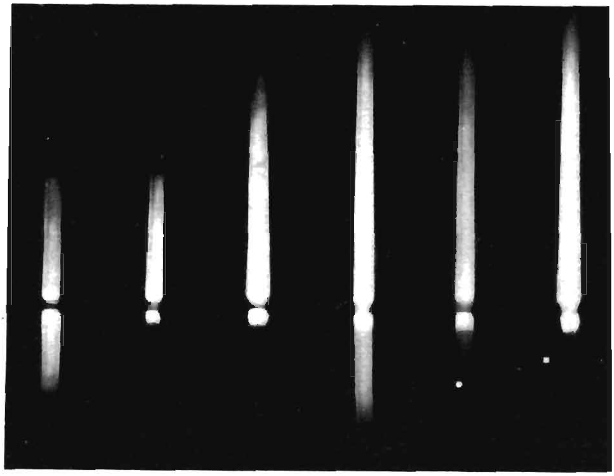
PLATE I

I II



IV

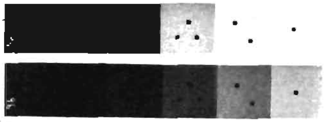
PLATE II.



I II III IV V VI

[*See page* [illegible]

A



B

A was taken with a spark coil with 6 M.A. and 12 seconds = 72 M.A. seconds.

B was taken with an alternating transformer, 6 M.A. 12 seconds.

In order to obtain with the latter a picture similar to A it was necessary to give an exposure of a little over 300 M.A. seconds with the alternating transformer.

[*See page* 23

area at a certain distance from this point. The illustration shows that at *twice* this distance the area which is exposed to the radiation is *four* times the size of the above rectangle; at *three* times the distance, that area has become *nine* times the size of the original rectangle. We see, therefore, that the single rectangle referred to above, which is struck by the full radiation at the first distance, is struck by only one quarter of that radiation at twice the distance, and one ninth of it at three times the distance. A photographic plate exposed at 40 cm. from the anticathode requires therefore four times as long an exposure to assume a certain tint as a plate exposed at a distance of 20 cm. A table showing the influence of the distance on the duration of the exposures will be found on page 127.

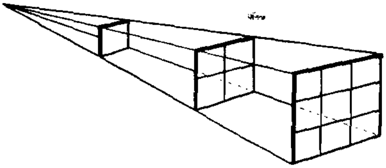


Fig. 4.

Absorption.—The fact that the hand held between the tube and a fluorescent screen causes a diminution in the brightness of the fluorescence shows that the X rays are being weakened by traversing the hand. Some have disappeared as X rays by being "absorbed" by the hand, and transformed into other energy, which produces biological, chemical and physical effects and changes. Only a part of the X rays traverses the hand unchanged.

As long as a comparatively low E.M.F. is sufficient to cause a discharge through the tube, the difference in the luminosity of those parts of the screen which are not covered by the hand, and those which are covered by it, is great, and so are the contrasts between the flesh of the fingers and the finger nails, or between the latter and the bones of the fingers. When the quantity of gases in the tube is further reduced, and the E.M.F. is increased, the brightness of the fluorescence increases, but the transparency of the hand increases at a much more rapid rate, so that when an equivalent spark of about 20 cm. has been reached, the parts of the screen covered by the flesh of the hand fluoresce with a light nearly as bright as those which are not covered, and the shadows of the finger nails and other fine details, which were clearly visible while a lower E.M.F. was used, have disappeared entirely (see *Plate I*).

This fact has certainly been observed by all soon after they began to use X rays, but the important lesson to be learned from it, i.e., that the finer details, which are so important in many cases for a correct diagnosis, **can only be obtained with a certain quality of X rays,** seems to be overlooked pretty frequently. It is therefore worth while to spend a few more lines on its explanation.

If we hold a sheet of aluminium, 1 mm. thick, behind the fluorescent screen, it will cast a shadow of about the same darkness as the flesh of a thin finger, or water 10 mm. thick. A second sheet of aluminium, placed above

the first, will cause an increase in the depth of the shadow, but will not quite double it. If we hold sheets of platinum and lead, 0·1 mm. thick, behind the screen, the shadows will be much darker than that cast by a sheet of aluminium 10 times as thick, but though the platinum and lead have the same thickness, and nearly the same atomic weight, there will be a considerable difference in the depth of the shadows: that produced by the platinum (atomic weight 194, specific gravity 21·5) will be much darker than that produced by the lead (atomic weight 206, specific gravity 11·3). The specific gravity has therefore a greater influence than the atomic weight.

These experiments show that the degree of absorption varies widely; it depends on:—

1. The degree of evacuation of the tube and on the E.M.F. applied to its terminals. The greater they are, the **smaller** will become the degree of absorption.

2. The atomic weight, the specific gravity, and the thickness of the media. The greater they are, the **greater** will be the degree of absorption.

Every medium has therefore its own coefficient of absorption, depending on its atomic weight and specific gravity, but this coefficient is by no means constant, it varies widely with the wave length of the X rays used.

Only the rays which are absorbed produce the physical, chemical and biological changes which make the X rays so useful for medical purposes; the rays which are being transformed into heat rays, and those which pass right through the media without undergoing any alteration, leave no effects noticeable to our senses.

Calculation shows that the intensity of the rays is bound to rise with the *square of the E.M.F. used*, but that the degree of absorption diminishes at a much *more rapid rate*. In consequence of this, the absorption which takes place in the fluorescent salts of screens, the bromide of silver of photographic plates, or in the cells of animal tissues, diminishes so rapidly, that the rise in intensity due to increased voltage does not produce effects *which are in proportion to this rise*; they appear to us much smaller than we would have expected.

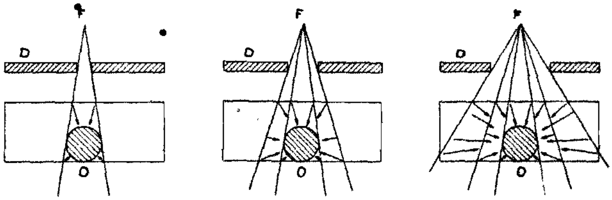
For diagnostic purposes, it is of great importance that the quality and quantity of the rays used should be suitable for the object, because the amount of details obtained varies with the quality of the X rays used. It must be just sufficient to penetrate the part of the body we wish to examine, and when this is the case we obtain the maximum of details and contrasts, and even the slight differences in density caused by tuberculous lesions, by diseases in the bones, small stones, calcifications, etc., will become visible. The further the penetrating power is increased, the more of the finer details will become transparent, and the outlines become obliterated by the scattered rays to be mentioned presently, so that only the bones will remain visible as faint shadows. Under-exposure cannot save the details.

For therapeutic exposures, there is an optimum in the quality too: the rays must have a penetrating power which is so great that they can reach the object to be treated without an undue part of them being absorbed by the supervening tissues; but it is useless to go far beyond this point, as the

absorption taking place in the objects diminishes rapidly with increase of voltage and the exposure would have to be prolonged unduly without any corresponding advantage.

Secondary and Scattered Rays.—Part of the X rays are converted into "secondary" rays. The penetrating power of these depends on the atomic weight of the medium which absorbs the primary rays; the secondary rays have invariably a lower penetrating power than the primary rays which cause their appearance. It is likely that most of the effects produced by X rays are caused by the secondary rays.

The X rays also become "scattered." When sunlight enters through a narrow slit into a clean medium like air or water, it will continue its path as a beam with sharply defined outlines. But when the medium is turbid, like milk glass, or when the air is full of dense fog or smoke, these sharp outlines disappear, and the neighbourhood of the beam becomes luminous too, because the rays are being deflected from their path. It is the same with X rays, but all media are turbid for them. The scattered rays tend to increase the intensity of the rays reaching an object, for while the primary



F = focus. D = diaphragm. O = object.

Fig. 5.

beam suffers losses through the inverse square law and absorption, that part of it which reaches the object is increased by scattered rays derived from those parts of the primary beam which traverse the body at a considerable distance from the object. This becomes apparent from the illustrations.

The scattered rays have the same penetrating power as the primary rays which cause their appearance. The greater the latter, the greater will become the radius of action of the scattered rays, but absorption and increasing distance cause them to become gradually weaker. At a distance of 10 cm. from their point of origin, they are too weak to exert a noticeable influence. Their importance increases with the volume and the depth of the tissues exposed to the X rays, as is apparent from the illustrations. The larger the diameter of the cone of rays entering the body, the greater will be the quantity of scattered rays generated. With very hard rays, and a diaphragm with an aperture of 18 × 18 cm., the influence of the scattered rays may cause the dose reaching a uterus to be nearly 3 times as large

as it would be with primary rays only, after making allowance for the losses due to increasing distance and absorption.

If the X rays are used for therapeutic purposes, the scattered rays are an advantage, because the total dose reaching the object is increased considerably (see tables on page 134). When the X rays are used for diagnostic purposes, the scattered rays are a great nuisance, because they tend to blur the outlines of the shadows, and many fine details which would be visible otherwise disappear in consequence. To reduce their quantity, a diaphragm is placed between the focus and the object to limit the cone of rays to a size just large enough to include on the picture all that is to be examined.

Homogeneous and Heterogeneous Rays.— Sparks obtained from transformers are not as instantaneous as they appear to our eyes. They last a certain, though very short, time (a few hundredth parts of a second).

This duration depends, in the case of spark coils, on the degree of self induction, the capacity of the condenser and on the interrupter used, as explained later on on page 18. In the case of closed iron core transformers it depends on the periodicity of the primary current. Both forms of apparatus are described later on. In either case the E.M.F. decreases rapidly from the maximum value.

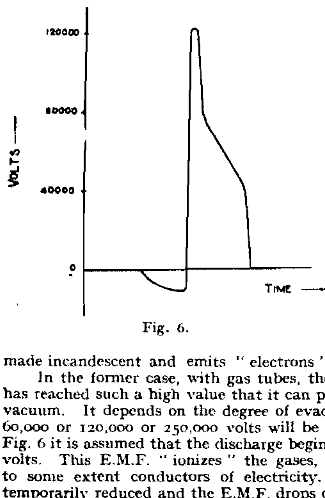


Fig. 6.

X-ray tubes are not conductors of electricity in the ordinary sense; they are insulators, until, in the case of gas tubes, the insulation has been pierced by a high E.M.F. which "ionizes" the remnants of gases, and while in this condition they conduct electricity to a certain extent, or until, in the case of Coolidge tubes, the cathode has been made incandescent and emits "electrons" which pave the way for a current.

In the former case, with gas tubes, the E.M.F. rises, *on open circuit*, until it has reached such a high value that it can pierce the insulation offered by the high vacuum. It depends on the degree of evacuation of the particular tube, whether 60,000 or 120,000 or 250,000 volts will be necessary till this can take place. In Fig. 6 it is assumed that the discharge begins when the E.M.F. has risen to 120,000 volts. This E.M.F. "ionizes" the gases, and while in this condition, they are to some extent conductors of electricity. The resistance of the tube is then temporarily reduced and the E.M.F. drops on "*closed circuit*" instantly about one third, as shown in Fig. 6.

As the E.M.F. of the induced currents continues to diminish gradually (see pages 18 and 23) the discharge continues with a gradually diminishing voltage, and comes to an end when the inducing current ceases (Fig. 6 shows this point to have been reached when the E.M.F. of the discharge has dropped to 40,000 volts), or when the E.M.F. of the discharge has become so low, that it can no longer overcome even the reduced resistance of the gap between the electrodes.

In hot cathode tubes, the path for the discharge is prepared by the electrons emitted by the incandescent cathode and the initial voltage need not therefore rise as high, but the gradual drop shown in Fig. 6 between the figures 80,000 and 40,000 volts takes place too.

The high voltage which is bound to precede each single discharge in a gas tube, and which is absent with hot cathode tubes, is the cause why, with the same

electrical apparatus, and the same primary current, rays of greater penetrating power, and greater intensity per M.A. of current, are obtained from gas tubes than from Coolidge tubes.

The voltage of each single discharge is therefore by no means constant, it begins with a considerably higher E.M.F. than that prevailing towards its end. We have already seen that the penetrating power of the X rays depends on the speed of the electrons which constitute the cathode rays and that this again depends on the E.M.F. between cathode and anticathode. We therefore expect that a current whose E.M.F. varies from the beginning to the end of each impulse, will produce a mixture of rays of all conceivable wave lengths, from one shortest wave length corresponding to the maximum value of the E.M.F. at the peak of the impulse right away to rays which have such long wave lengths as to be stopped by the glass. Actually, this is the case, but the explanation is not quite as simple and has an important bearing on future work.

The intensity of an X-ray beam depends on the square of the exciting voltage. Therefore the contribution of X rays to the heterogeneous beam from a tube falls off very rapidly with fall of E.M.F.—in other words, only the peak voltage is of importance in producing X rays. Those due to any other part of the impulse are negligible for practical purposes.

But even the rays produced by the peak voltage are a mixture for the following reason. The X rays are a result of collisions between electrons of the cathode stream and atoms of the anticathode. A head-on collision after which the electron stops dead, having been robbed of all its energy, produces the shortest possible wave length. A glancing collision in which the electron loses part of its energy, produces the same short wave length but a smaller intensity. The electron passes on with diminished speed, and at the next collision produces a radiation of longer wave length. A moment's reflection tells us that of all the wave lengths between the one at the boundary which is produced by primary collisions, and longer ones which are due to secondary or tertiary collisions, one will be greater in intensity than all the others. Even if the voltage of the discharge could be maintained at a constant level, by using for instance 50,000 volts from a battery of accumulators, instead of the impulses of induced currents, the discharge would not supply rays of uniform wave length, i.e., the rays from X-ray tubes cannot possibly be made homogeneous in the *physical* meaning of this word.

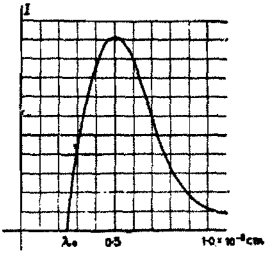


Fig. 7.

We can, then, draw a curve in which we show the intensity of the rays on the vertical scale against the wave length on the horizontal, and it looks like Fig. 7, beginning sharply at the shortest wave length which is due to head-on collision of electrons propelled by the maximum E.M.F. of the current impulse. From there the intensity rises rapidly to a maximum value at the wave length which is produced by that type of atom-electron collision which occurs most often—and then it dies away.

The interesting point about this, which has been proved both theoretically by March and practically by Benken, Ulrey, Harlowe, etc., is that we get the same mixture of rays from any apparatus, no matter whether it is spark coil, closed iron core transformers, gas tube or Coolidge tube, so long as the peak voltage remains the same. The actual quantity of X rays may vary, but the relative quantities of each wave length in the mixture remain the same. In physical language we say that the energy distribution through the spectrum remains the same.

The absorption which takes place when the rays pass through matter tends to make the rays gradually more homogeneous. After a bundle of heterogeneous rays has traversed the hand or a filter, its intensity has been weakened, but

as the soft rays have been absorbed and weakened to a much larger extent than the hard ones, the composition of this bundle has become changed, and it now contains a higher percentage of hard rays than it did before.

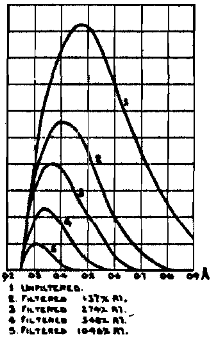


Fig. 8.

Filters.—If we use metal filters of sufficent thickness or density, the medium and soft rays can be absorbed to such an extent that all those rays, for instance, which would be heavily absorbed by the skin or superficial tissues are eliminated *before they reach the skin*. The rays are not transformed in any way into another wave length, and it would be useless to attempt to use filters with *soft* tubes. Hard rays cannot be expected below a filter unless they are generated by using highly evacuated tubes and high E.M.F.'s. The hard rays predominate after filtration only because the soft ones have been absorbed by the filter to a much larger extent, but the hard rays become weaker too. In fact, if we once examine the intensity-wave-length curve which has just been alluded to, we find that filters move the energy maximum towards the minimum wave length and decrease it at the same time (see Fig. 8).

The degree of filtration depends on the atomic weight and specific gravity of the metal used, and on its thickness. It is not possible by filtration to make the X rays "homogeneous" from the physicist's point of view, but when it has been carried so far that, for instance, a 10 mm. layer of tissues of the body *nearest the skin* absorbs the same percentage, and no more, of the X rays which reach it as a layer of similar thickness 5 or 10 cm. *below* the skin, we say that the rays have become "homogeneous for *biological* purposes." To reach this degree of homogeneity for the human body, it is necessary to use aluminium filters no less than 12 mm. thick, or zinc or copper filters 0·5 mm. thick. The latter are preferable, partly because sheets 12 mm. thick become inconvenient, and partly because they scatter the rays too much.

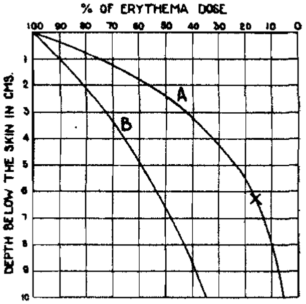


Fig. 9.

A represents the passage of an unfiltered beam; it begins to get homogeneous near X. B represents the same beam filtered through 0·5 mm. copper.

For some deep-seated malignant diseases, even thicker filters, 1 mm. copper, 3 mm. zinc, or a lead foil 0·12 mm. thick, have been used. They

were embedded between two sheets of aluminium, 1 mm. thick, to protect them from injuries. Exposures lasting 5 to 8 hours were necessary to produce the erythema dose, and it is doubtful whether any better results were obtained. Zinc or copper absorb nearly 30 times as much of the X rays as aluminium of similar thickness. When zinc or copper are employed as filter, it is advisable to use in addition an aluminium filter 1 to 2 mm. thick just below the heavy filter, to absorb secondary rays which may be started from these heavy metals.

Filters are indispensable for all therapeutic exposures, as we shall see later on. Even for some diagnostic exposures it is advisable to use aluminium filters 0·7 to 1 mm. thick. For many other diagnostic exposures, it would be an advantage if the *hard* rays could be filtered out, so that only those of medium penetrating power reach the patient, but this cannot be achieved.

THE ELECTRICAL APPARATUS.

The E.M.F. of the electric currents used for lighting our houses does not exceed 200 to 250 volts. This is quite insufficient to leap across the gap between the cathode and the anticathode of any X-ray tube; some 20,000 to 200,000 volts are necessary for this purpose, according to the degree of evacuation of the tube used. These high voltages can best be reached by induction and transformation. The transformers most frequently used are *spark coils* (transformers with an open iron core and operated by an interrupter) and *closed iron core transformers* (operated by an alternating current).

Spark Coils.—The essential parts of a spark coil are: a primary coil, consisting of a number of thin sheets of a special magnetic iron, round which about 200 turns of thick copper wire are wound. This is placed in a stout ebonite tube, to insulate it from the secondary coil. The latter consists of many thousand turns of a thin copper wire, wound in some 100 thin vertical sections.

If we send a current through the primary wire, the iron becomes magnetized and a magnetic field is created. The appearance or disappearance of this field, or any change in its intensity, induces currents of short duration in the secondary coil. Their intensity depends on the intensity of the magnetic field, and the *suddenness* of its appearance or disappearance.

Self Induction, Reverse or Closing Current.—When the primary current is closed, an induced current appears not only in the secondary coil, but in the primary as well. This "extra current" is due to the action of the magnetic field on the turns of wire on the primary, and on the action of the turns of wire on each other. This is called the "self induction." Its intensity depends on the number of turns of wire on the primary coil, on the E.M.F. used in the primary circuit, and on the intensity of the magnetic field. The self induction in the primary of a spark coil made for X-ray

purposes can reach an E.M.F. of 3000 volts. In *closing* the primary current, this extra current has a direction *opposite* to that of the primary current, and therefore forms a resistance or obstacle, and *retards* the increase of the primary current. The greater the degree of self induction, i.e., the larger the iron core, and the greater the number of turns of wire wound round it, the more time will it take before the primary current and the magnetism can reach the maximum. On *breaking* the primary current, this extra current has the *same direction* as the primary current, and causes the very strong spark which appears in the interrupter. This spark forms a bridge of rapidly increasing resistance, through which the primary current can continue to discharge ; the circuit is broken only when this spark is extinguished. As the intensity of the induced current varies with the *suddenness* of the disappearance of the primary current, and the magnetic field, one must aim at extinguishing this spark in the interrupter rapidly. This can be achieved in various ways : A condenser is connected with the interrupter, so that another path is open to the extra current. If the capacity of the condenser is chosen suitably, the length of the spark induced in the secondary circuit on breaking the primary current will be over five times as long as it would be without a condenser. With the modern interrupters care is also taken that the distance between the contacts of the interrupter increases rapidly, and that the break takes place under a dielectric, paraffin oil, alcohol or coal gas, to extinguish the sparks more quickly than air can do it.

Reverse Current.—It is of great importance that we have means to extinguish this breaking spark in the interrupter rapidly ; if this were not the case, the secondary current induced on *breaking* the primary current would scarcely be stronger than the current induced on *closing* the primary current. The existence of this latter current, which is called reverse or closing current, is a great inconvenience in X-ray practice, as we shall see later on, but by suitable construction of the spark coils it can be kept so low that its E.M.F. is insufficient to overcome the resistance of the X-ray tubes.

Length and Voltage of the Sparks.—The E.M.F. or spark length to be obtained from the secondary coil increases with the number of secondary turns used, because the E.M.F.'s induced in all the single turns add up. By choosing the number of turns suitably, we can, for instance, transform a primary current of 200 volts to 50,000 or to 200,000 volts, but the number of ampères are reduced in proportion, because though the relative number of the volts and ampères can be *changed* by transformation, their product, which is the total energy, can of course never be *increased*, as this would be against the law of the conservation of energy. If the transformation could be effected without any loss, a current of say 200 volts and 10 ampères = 2000 watts, could be transformed for instance into 50,000 volts and 0·04 ampères (40 Mil. Amps.) which represents again 2000 watts, but as losses occur in every transformation of energy, the current obtained under the above conditions will be between 20 and 30 Mil. Amps. only, instead of reaching 40 Mil. Amps. A table showing the E.M.F.'s required to overcome the resistance of different lengths of air gaps between a point and a plate, will be found on

age 126. The spark length increases at a much quicker rate than the voltage; 2,000 volts are necessary to produce a spark 20 cm. long, but 180,000 volts, e., about double the voltage, already give sparks 55 cm. long.

The coils are provided with discharging rods; one of these usually ends 1 a point, and the other is provided with a plate. This arrangement helps 2 detect the polarity. The sparks can discharge easily, from the point to *ny part* of the plate, while the latter is the *negative* pole or cathode, and the oint the anode or positive pole, as shown in Fig. 10. If the point were the

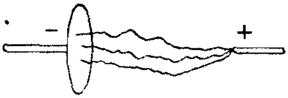


Fig. 10.

Fig. 11.

egative pole, the sparks would invariably discharge between the *edge* of the late and the point, as shown in Fig. 11, and would then be shorter than hen discharging the correct way.

Measuring the Intensity of the Secondary Discharge.—Spark coils were ormerly classified only according to the *length* of the sparks which they can ive. This is almost useless; it means only that a coil has a sufficient voltage) overcome the resistance of an air gap 20 or 40 cm. long, but just as the ower of a waterfall is not determined by the head of the water alone, but y the head × the quantity of water which is available, so for X rays the ower depends on the number volts × M.A. which the coil in produce. A 10″ coil with hich say 20 M.A. can be proiced through a tube with an quivalent spark of 15 cm. is better and will give shorter exposures for diagnostic purposes than a 20″ coil which produces only 2 M.A. through the same tube.

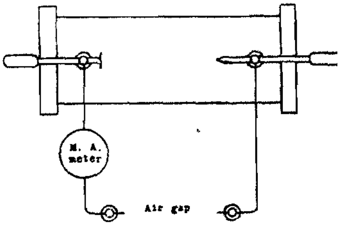


Fig. 12.

Although it is not yet possible to measure the intermittent currents of high voltage obtained from spark coils as accurately as we can measure the current from batteries or dynamos, it can be done sufficiently well, and it is of great importance that in addition to the spark length the number of M.A. which a coil can give should be stated.

The most natural thing would be to measure the number of M.A. which can be obtained through X-ray tubes; but as a standard for comparison this is impossible, because there is too great a difference in the resistance of various tubes; the hardest ones have ten times as much resistance as the softest ones. We can, however, measure the number of M.A. obtained through an air gap. Its resistance depends on its length. The M.A. meter is to be connected, as shown in the sketch. I have found that *those coils which give the highest number*

of M.A. through an air gap, give the highest number of M.A. through a tube. good coil for diagnostic purposes will give

through air gaps	100	50	20	M.A.
	20	30	40	cm. long.

The long air gap acts also like a valve, and excludes the reverse current This method gives fair information about the real power of a coil, and is s simple that every owner of a spark coil and M.A. meter can use it.

The efficiency of various types of spark coils and transformers can als be tested by exposing photographic plates under suitable test objects, fc instance, aluminium ladders of increasing thickness.

The most accurate test is to examine the rays which a certain coil c transformer will cause to be emitted from an X-ray tube as to their qualit by measuring the boundary wave length on a spectrometer (see page 43), an as to their intensity on the ionto quantimeter (see page 47). In this way correct value of the output of the apparatus can be obtained.

For **Coils for Diagnostic Purposes** it is no advantage to have a penetratin power much greater than that which is sufficient to make the part of th body to be examined transparent. If the E.M.F. used were too great, th duration of the exposure could be reduced, but the scattered rays would increas too much, and small differences in density would not cause a shadow to be projected, and the bromide of silver of the photographic plate would become more transparent too and absorb a smaller quantity of the rays, so that thin foggy negatives without details and contrasts would be the result. X rays of medium penetrating power, with wave lengths varying from about 0·40 to 0·20 Å.U. give the best negatives, with most details and fair contrasts (see tables on page 130). Sparks 20 to 30 cm. long are sufficient for diagnostic purposes, but the *number of M.A. should be as great as possible*, because frequently it is a great advantage to be able to give very short exposures, as in many cases a reliable diagnosis is impossible if the exposures last longer than the patient can easily keep his breath. The excursions of a stone in the kidney, due to respiration, may make it or other fine details become invisible. In some cases the exposures should even be finished in a small fraction of a second, to avoid the loss of sharpness caused by the movements of the heart, the peristaltic movement, or by restless children. For the most difficult exposures—for instance, if the fine structure of bones has to be shown to detect tuberculous lesions, or the presence, size and position of an intra-uterine embryo—apparatus giving sparks of about 10 to 15 cm. only, but currents of 50 to 150 M.A. are best.

For **Coils for Therapeutic Exposures** the conditions become different, especially if deep-seated organs like the ovaries or uterus have to be treated.

For some skin-diseases, the 14-in. coils made for diagnostic purposes can be used without any alteration. But if the action of the rays is desired a few mm. below the skin, it is necessary to employ hard rays, because those of medium penetrating power will be stopped and absorbed by the surface of the skin, and may cause an erythema or even dermatitis long before the deeper-lying parts have received a dose sufficiently strong to cause the desired injuries on deeper-lying cells. For the majority of therapeutic exposures,

e 20-in. coils are preferable. They give a voltage which is sufficient for oducing sterilization of the ovaries; but to obtain the hardest rays required : the treatment of deep-seated malignant diseases, coils giving about o,000 volts are necessary, and as some spare power is desirable, they are ually wound so that they can produce currents of some 250,000 volts and arks up to 70 cm. long.* In spite of these very high voltages, they can vertheless be used for diagnostic purposes, provided that *very soft* tubes e employed. Currents of some 15 M.A. can then be obtained, and the M.F. drops so far that the rays are not too hard for diagnostic purposes, d very fair negatives can be obtained even with these coils.

The insulation must be suitable to withstand this pressure, the secondary nding has to be protected against oscillatory discharges, but more importnt than this is the fact that coils intended for therapeutic exposures have be provided with condensers of much larger capacity.†

The number of cases in which X rays are used in gynæcology is increasing so rapidly that many hospitals have apparatus fully occupied with these cases every day. For such installations the coils must be provided with an arrangement to prevent overheating even with such prolonged use. For this purpose an air space is left between the primary and secondary coil, to allow the heat to be carried off by a current of air, and the coil is mounted vertically. If the apparatus are to be used for some eight or more hours every day, the cooling can be better achieved when two separate short coils are connected in series than when one larger coil is used.

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* As matters stand at present, it is no advantage to use coils or transformers giving much more than 200,000 volts. Apparatus supplying 300 to 500 kilo volts have been tried already, but with the tubes available the intensities increase but little when 200 *kilo volts are exceeded, the lifetime of the tubes becomes very short, and the difficulties* with insulation, brush discharges, etc., increase rapidly. Much more important than this is, that, while the intensity of the X rays increases as the square of the exciting E.M.F., the absorption of those rays by the tissues *decreases* as the fourth power of the E.M.F., owing to the shorter wave length of the radiation. Moreover, it has been proved that the biological effect of hard rays is considerably smaller than that of soft rays. To produce the *same biological effect*, 3·9 times more of the hard rays have to be absorbed than of the soft ones, or, when similar quantities have been absorbed, rays with a wave length of 0·56 Å.U. have biologically 3·9 times as great an effect as rays with a wave length of 0·325 Å.U.

Professor Russ published in the *Lancet*, 1923, pages 637–640, some experiments made in the Cancer Laboratories of the Middlesex Hospital. He states that: "When equal amounts of X-ray energy are absorbed from beams of different wave lengths by animal tissues, the reaction of these tissues may differ considerably in degree and possibly to some extent in nature. A bigger differential effect between hard and soft rays exists for the skin of the rat than for the tumour cells. Six times as much short wave-length energy must be expended in a layer of skin, in order to produce equal reactions, and this factor falls to about 2·6 in the case of a tumour." (He compared the biological effect of "soft" rays, of wave length $\lambda = 0{\cdot}4$ with "hard" rays, of wave length $\lambda = 0{\cdot}168$. The figures found by Prof. Russ agree well with those mentioned above, which were found by Professor Martius.)

The only possible advantage would arise if it were proved that hard rays, in spite of their smaller quantitative effect, produce *better results*; but no evidence of this has yet been forthcoming.

† As the cause of this is not apparent at first sight, I will try to explain it. It has already been mentioned that the primary current can continue to discharge till the spark appearing in the interrupter has come to an end, and that the magnetic field decreases gradually only; the consequence of this is that the secondary discharge continues too,

Interrupters.—The function of the interrupter is to close and open th primary circuit in regular, rapid succession. The intensity of the X ray emitted by the tubes depends on the intensity of the single electric impulse: multiplied by their number. When the intensity of the discharges remain the same, an exposure can be reduced to one-half the time when the numbe of discharges in a given time is doubled.

The intensity of the single discharges varies with the strength of th primary current used, the size of the transformer and iron core, the numbe of turns, etc., but it is influenced also to some extent by the frequency c the interrupter. Owing to the self induction, the magnetic field requir a little time to reach its maximum. If the interruption takes place befor this has been reached, the discharge will be less intense than when th " duration of contact " lasts a sufficiently long time to allow the iron co to become nearly saturated with magnetism. When a certain frequency i exceeded, this duration of contact is bound to become too short, and th single discharges will then become less intense ; whether this will happe

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till the spark in the interrupter has been extinguished. If the picture of the discharg produced in an oscilloscope tube is examined in a revolving mirror, it looks like Fig. 1; The highest peak is due to the high E.M.F. prevailing at the beginning of the discharg but this E.M.F. diminishes quickly, the discharge can, however, continue, because aft the gases in the tube have become " ionized," they offer less resistance to the passag of current, and a comparatively low voltage can pass through even a hard tube at the ta end of a high E.M.F. impulse. We have already seen (p. 11) that these lower E.M.F.'s i an impulse have no effect for practical purposes on the X-ray mixture produced, but th is the same as saying that the M.A.'s through the tube are useless as soon as the E.M.I falls from the peak. To obtain a large intensity of X rays our object must be to mak the peak voltage endure for as long a time in the impulse as possible. Unless this is th case, there will be too small a quantity of hard radiation below the filter.

The peak can be influenced by using condensers of suitable capacity ; for therapeut exposures of deep-seated organs it has to be about ten times as large as that which ha been found sufficient for coils for diagnostic purposes. Such large condensers can bett absorb the strong currents causing the sparks in the interrupter which prevent the primary current from coming to an end, an more of the discharge through the tube passes at the pea voltage. The current curve assumes the shape shown in Fig. 1. The intensity of the rays available below a heavy filter, an the percentage of the surface dose penetrating to deep-seate organs, become greater, and the duration of the exposu shorter, when a large condenser is used.

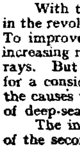

Fig. 13.

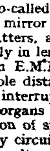

Fig. 14.

I may add here a few other remarks. With an electrolyt interrupter, the breaking spark is extinguished so rapidly th no condenser is required. They are therefore suitable too, pr vided the self induction of the primary is carefully chosen s that the frequency of the interruptions does not become excessiv

With the so-called interrupterless transformers, to be described later on, the pictu in the revolving mirror looks also like Fig. 13, and a condenser cannot be used in this cas To improve matters, a revolving arm interposes a resistance, consisting of an air ga increasing rapidly in length, to cut off the tails of the discharges which produce the soft rays. But with E.M.F.'s of over 50,000 volts, a strong spark follows the revolving ar for a considerable distance and the object is only imperfectly achieved. This is one the causes why interrupterless transformers are less suitable for the therapeutic exposur of deep-seated organs than spark coils.

The insertion of spark gaps, in series with the X-ray tube, increases the resistan of the secondary circuit. This helps to suppress the closing current, which may appe when very high voltages are being used, and the path for discharges of moderate E.M.F. at the tail end becomes blocked earlier, but the intensity of the discharges is slight weakened too, and as the additional resistance absorbs some part of the voltage, spa gaps tend to make the rays a little weaker and softer.

ter 20, 40 or 60 interruptions per second have been exceeded, depends o e size of the iron core, the number of turns of wire on it, the E.M.F. use the primary circuit, and on the construction of the interrupter. Th quency with which the most intense single discharges can be obtained wit particular apparatus can be found out accurately with the spectromete or approximately with the length of the fluorescent band of an oscilloscop tube or with tests on photographic plates.

What is the best frequency? X-ray tubes stand even very intens discharges *well if there is a reasonable interval between two succeedin* discharges, whereas high frequencies are a great strain on them, even if th intensities of the single discharges are small. With exposures lasting longe than 2 minutes, frequencies exceeding 50 per second should not be used

About 40 interruptions per second are the rule for most exposures give in the treatment of skin diseases; for the exposures for deep-seated organs it is certainly worth while to find out by experiment whether the discharge of greatest intensity will be obtained with the particular apparatus with 30 40 or 50 interruptions per second, the difference in the result may reach 1 to 15 per cent, and this is well worth having when the total duration of th exposures may reach several hours.

For examination on the fluorescent screen, the frequency should not b less than 40 per second, as otherwise the light will appear flickery to ou eyes, but it should not be more than 50 or 60, to avoid the strain on th tubes if the examination should last many minutes. For the short exposure required for making negatives, no harm will be done to the tubes if frequencies of even a few hundred per second are used.

Mercury Interrupters.—The motor-driven mercury interrupters are mos frequently used. There is a large variety of them. The interruptions tak place under a dielectric, which helps to extinguish quickly the strong spark appearing on breaking the primary current. Paraffin oil, alcohol or coal ga can be used for this purpose. The first mentioned is the most efficient, but tends to form a dirty emulsion with the many thousands of very small drop of mercury, so that the latter has to be cleaned comparatively frequently. Coal gas is much better in this respect, and is therefore preferred for exposure of long duration. The gas has to be renewed every morning, but this i accomplished by merely opening a tap for a few seconds. If a gas supply is not available in the house, gas compressed in a small steel cylinder may be used.

Good interrupters of this kind can be used 10 hours every day for many months, without requiring any other attention, and give as little trouble a the motors with high tension current reversers to be explained on the next page.

For many years, interrupters of small size were used, because in the early days of X-ray work they were sufficient, but when the tubes had been improved so far that very intense discharges could be used with them, and when exposures of long duration began to be required for therapeutic purposes, they proved insufficient, became hot, and had to be cleaned too

frequently. Much larger interrupters with more than ten times the capacity are made now, which can interrupt currents of even four kilo watts, and which will work as smoothly as large motors or dynamos.

In one class of mercury interrupters, a contact dips into the mercury; the interrupter invented by the late Sir James Mackenzie Davidson is the best of this class, because the mercury is kept rotating, and the drops separated by the action of the dipper thus become reunited with the mass of mercury. In other interrupters, the centrifugal power makes the mercury form a ring in the periphery of a pear-shaped vessel, a revolving segment is pressed into this ring, a very intimate contact is thus established, and sparks of great intensity can be produced with these interrupters. In a third class, a revolving tube ejects mercury, also by centrifugal power, which alternately strikes contacts or insulators.

With most interrupters, the duration of the contact can be varied a little, independently of the frequency of the interruptions. The number of revolutions of the motor per second has an influence on the duration of contact too, and this number can be varied with a rheostat in fairly wide limits. With some interrupters, the number of contacts per revolution can be altered, so that either one or two, or else two or four contacts can be made per revolution. When the number of discharges in a given time is thus doubled, without altering the duration of contact, the intensity of the rays reaching an object is doubled too, and the duration of the exposure can be reduced to one half. This is an advantage for making negatives, but for exposures of long duration the high frequencies cannot be used, because the strain would become too great for the tubes.

Electrolytic Interrupters.—An interrupter based on a totally different principle was invented by Prof. Wehnelt in 1899. In this interrupter a thin platinum wire and a large lead electrode are immersed in diluted sulphuric acid, 1 oz. acid to 5 oz. water, or 20 to 25 Beaumé. When a current of not less than 50 volts and 5 ampères is passing through this in such a manner that the platinum is the anode, the density of the current is so great that the small anode becomes very hot, and steam is formed. In addition, electrolysis causes hydrogen and oxygen to appear, and these gases form an insulating mantle round the anode which interrupts the current. If there is a sufficient amount of self induction in the circuit, a spark appears at the breaking point, i.e., the anode, ignites the gases, and after the explosion the acid again gains access to the platinum, thus closing the current once more. This process takes place with extraordinary rapidity and regularity. The intensity of the single discharges and the frequency of the interruptions can be varied in wide limits by varying the E.M.F. used in the primary circuit, the surface of the platinum anode, and the amount of self induction.

Interrupters for Alternating Current offered great difficulties for many years. They are no use unless the primary current is broken at the moment when the wave of the alternating current has reached its greatest height. Perfect synchronism between the motor driving the interrupter and the dynamo generating the alternating current at the central station is therefore

ssential condition. For a long time the motors used for the interrupters e too small; they ran in synchronism well enough as long as the primary ent was *not switched on, but they fell out of step as soon as this was* e. This difficulty has now been overcome, at any rate for those circuits re the periodicity used is between 40 and 60. Interrupters are available *which work so well on this periodicity that the output is exactly the* same as that from a continuous current circuit. The primary coils have to be wound specially to be suitable for alternating currents.

If, however, the periodicity is above 60, it is more difficult to maintain synchronism, and the high frequency makes the interrupters less satisfactory. In towns where the periodicity is above these limits,

Motor Transformers have to be employed to convert the alternating into a continuous current. A motor driven by the alternating current is coupled to a dynamo which delivers a continuous current. The size ought to be chosen so that at least 2000 watts can be obtained from the latter. These motor transformers are very reliable, easy to work, have practically no wear and tear, and require scarcely any attention. They can be placed in the X-ray or any other room, or the basement, but should have a good bedplate and should not be fixed on a hollow resounding floor.

Interrupterless Machines consisting of Closed Iron Core Transformers operated by an Alternating Current with or without High-tension Rectifier.— There is yet another way of utilizing for X-ray purposes the alternating current which we obtain either straight from the main or by converting the continuous current. It can be transformed into suitable high voltages by alternating current transformers and the waves can be made unidirectional by means of a rotating high-tension rectifier driven by a synchronous motor.

It looks at first sight as if a much larger quantity of X rays could thus be produced, but limits are drawn with this system too.

The rapid break taking place in an interrupter causes a rapid disappearance of the magnetic field, and for this reason high voltages and intensities of X rays can be reached with spark coils of comparatively small size; whereas with the more gradually ascending and descending waves of an alternating current (see Fig. 15) very much larger transformers are required to reach similar voltages and intensities.

This is most felt in the case of therapeutic exposures, where high voltages are indispensable to produce X rays of great penetrating power, which can be reached more easily with spark coils, but even for diagnostic exposures, where soft rays are an advantage, the initial cost of an interrupterless high-tension transformer is fully twice as great as that of a spark coil outfit giving the same intensity. The consumption of current is greater too, but the absence of an interrupter is considered an advantage by those who are inexperienced in technical matters.

The fact that comparatively low voltages only are available—these transformers are usually constructed to give as maximum, sparks 10 in. long— makes it easier for nurses, etc., to turn out a good quality of negatives, even

in such difficult cases as renal calculi, tumours, diseases of bones, intra-uterine embryos, etc., whereas with spark coils giving 14 to 20 in. sparks, a little more knowledge and experience is required to control the discharge and the tubes, so that the quality of the rays is not too hard for faint objects, and that foggy, thin negatives without contrasts are avoided.

One and the same tube will give considerably softer rays when used on a transformer than on a spark coil (see also foot note).

This is due to the fact that the intervals of rest between two succeeding discharges are so short, when an interrupterless transformer is being used that the ionization of the gases, which possesses some slight inertia, does not disappear entirely before the next discharge begins. With a spark coil this interval of rest between two succeeding discharges is *at least* three times as great as the duration of the discharge itself, even if very high frequencies

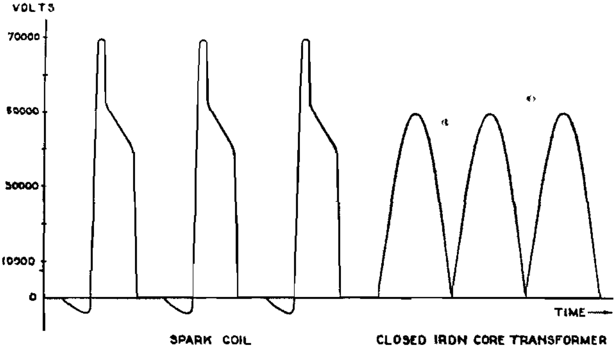

Fig. 15.

of the interrupter are being used. (For want of space Fig. 15 does not show these intervals in true proportion.) The consequence is, that with spark coils the E.M.F. must rise to a considerably higher value before a discharge can begin than is the case when interrupterless transformers are being used (see also page 10). The discharges produced with the latter contain therefore a lower percentage of hard rays than those produced with spark coils. For diagnostic purposes this is an advantage ; for therapeutic exposures a high percentage of hard rays are necessary.

The number of milliampères which can be reached with an interrupterless

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I have noticed this in 1909 already, and drew attention to it in a little pamphlet published in 1910. It was considered so unlikely at that time that a Professor of Physics wrote to the *Archives* saying that I must have made a mistake. But after a private correspondence which followed, he agreed that I might be right, and this difference in hardness is admitted now, see for instance *Archives*, April, 1924, page 85, "Quality of X Rays beam in relation to alternative spark gap " by H. Moore.

transformer is considerably greater, but *the quantity of X rays obtained per M.A. of current is somewhat smaller* than is the case when a spark coil is used. This is due to the fact that X rays of sufficient hardness to penetrate the glass wall of the tubes are generated only while the E.M.F. of the discharge exceeds about 25,000 volts. With the spark coils used for X-ray purposes, this exists during almost the whole duration of the discharge, but with interrupterless transformers it is lower at the end of each wave. Though the circuit is closed by the rotating high-tension rectifier only when the wave has nearly reached its peak, it cannot be interrupted as early as would be desirable, because a strong spark follows the interrupter for a considerable distance. The circuit thus remains closed, and the current can continue to produce heat and to influence the M.A. meter for some time after the E.M.F. has dropped below the point at which X rays of sufficient hardness are generated to penetrate through the glass wall of the tube.

The actual composition of the bundle of X rays produced by the spark coil and the closed iron core transformer is the same for each provided the peak voltage is the same (see page 11), but the fact that the transformer wave sinks more gently to zero than that of the coil causes current to flow through the tube for some time after the generation of any useful X rays

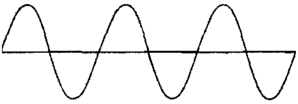


Fig. 16.—Alternating current.

Fig. 17.—Alternating current rectified by revolving synchronous current reverser.

Fig. 18.—Alternating current rectified by Coolidge tube.

has ceased. This current, at voltages considerably under the peak, heats the anticathode and is the reason why the wear and tear on X-ray tubes is rather greater with a transformer than with a coil.

A considerably larger number of milliampère seconds has therefore to be used for exposures than is mentioned on page 68, which are correct for coils and gas tubes only (see tables 10 and 11, page 130).

Spark coils and interrupterless transformers with a high-tension rectifier may be employed with either gas or Coolidge tubes.

When Coolidge tubes only are employed, the rotating high-tension rectifier may be dispensed with for *some* exposures, because these tubes act like a valve and suppress the currents in the wrong direction *as long as the anticathode remains cool.*

This is due to the fact that the tubes which have been completely exhausted permit no current to pass at all, so long as the electrodes are cold. As soon as they are heated to incandescence, they emit electrons while in contact with the *negative* pole of a source of electricity of high E.M.F. As long as the *cathode only* is heated, an alternating current can discharge in

the correct direction only and the second phase of each wave is suppressed; but when the anticathode becomes hot too, an effect which the bombardment of the electrons will produce pretty soon when strong currents or prolonged exposures are used, it begins to emit electrons too, and the valve action comes to an end. Furthermore, these electrons are converted into X rays when they strike the cathode and the walls of the glass. They may even bring the latter to melting point and the negatives become blurred and useless.

The omission of the rotating high-tension rectifier, and the synchronous motor required to drive it, makes the initial cost less and the management of the apparatus a little simpler, but with apparatus built on these lines the exposures required are bound to be more than twice as long as with apparatus which are provided with the rectifier, because the latter uses twice as many phases (see Figs. 17 and 18), and because the tubes can admit more of the rectified current as long as it has not to suppress one phase.

The apparatus without the rectifying current reverser are therefore not suitable either for exposures which should be finished in a very short time, or for the more difficult cases in which small stones, diseases of bones, tumours, etc., have to be shown, partly because the focus of the Coolidge tubes is not yet so well suited to bring out the finest details, and partly because such cases sometimes require prolonged exposures. They are not suitable either for therapeutic exposures, but they are quite sufficient for examining most cases occurring in general practice—fractures, foreign bodies, the heart, lungs and some other cases—and are therefore sufficient for many general practitioners and dentists residing in districts where the alternating current is laid on. The management of these apparatus is exceedingly simple and easy.

Electric Supply and Rheostats, etc., to control it.—I have yet to mention the sources of electrical energy which are necessary. Wherever the continuous current is laid on this should be used; it is the most convenient current. For mercury interrupters and spark coils, we require usually from 5 to 10 ampères, for electrolytic interrupters and for transformers with high-tension rectifiers, up to 25 or even 40 ampères. If an alternating current with a periodicity of 40 to 60 is available, it may be used directly with mercury interrupters. If the periodicity exceeds 60 considerably, it is better to transform the alternating into a continuous current by means of a motor transformer, as has been explained already, or to use it with an interrupter-less high-tension transformer with synchronous rectifier.

A *Switchboard* is required in most cases. They consist of a marble or slate plate, on which are mounted a main switch, to turn the current on or off, and a variable resistance to control the strength of the primary current. A volt- and ampèremeter, to measure the primary current, are most desirable. The switchboards are moreover provided with a switch and variable resistance to control the motor of the interrupter, a signal lamp to indicate whether the apparatus are turned on or off, fuses as protection in cases of accidental short circuit, and terminals for the convenient connection of t

All parts carrying current, i.e., the terminals, the contact pegs of the resistances, etc., should be protected by insulating material, so that they can not be touched accidentally in the dark.

In more elaborate installations, the switchboards can be provided also with a switch to insert either a mercury or an electrolytic interrupter, and with a switch and clockwork to break the primary current automatically after a previously set time, which can be varied from 0·1 to 10 seconds.

Shunt or Series Rheostat?—The switchboard can be arranged so that the rheostat is "in series" or "in shunt" with the dynamo. In the former case the full voltage of the supply has to be used, and can be reduced a little only by inserting resistances. In the latter case, the *voltage* can be reduced and varied in wide limits. This has decided advantages, if moderate or weak currents are required, because the variable voltage in the primary gives a better control over the discharge. For instance, with a 16-in. coil, a mercury break, and a resistance of 35 ohms, on a 240-volt supply, the shortest spark I could obtain with the rheostat "in series" was 5½ in. long, i.e., the discharge rods had to be separated 5¾ in. to prevent the sparks from discharging, whereas the shortest sparks obtainable with the *same* resistance in a "shunt" were only 1¼ in. long. With a shunt the discharge can therefore be varied in wider limits, and it can better be adapted to medium and soft tubes than is possible with the connection in series.

The better switchboards are so arranged that the rheostat can be placed "in shunt" or "in series" at the will of the operator, by closing or opening an additional switch which is marked "Shunt."

Accumulators.—If no current from the main is available, accumulators may be used, provided there is an opportunity of getting them recharged. It must be understood, however, that the exposures will have to last a considerably longer time, because with 12 accumulators we cannot produce nearly the same intense discharges which can be obtained with the 100- or 200-volt currents from dynamos.

Gas or Oil Engines can be used very well to drive a dynamo. The oil engines are similar to those which are used for automobiles. They are so perfect and reliable now that they can be started easily; they are also portable so that they can be used in field hospitals. For a coil with a mercury interrupter, engines of 3 to 4 H.P. are quite sufficient. They may be used also for lighting small hospitals or private houses.

X-RAY TUBES AND THEIR TREATMENT.

The quality of the X-ray tubes is of the greatest importance for success in X-ray work; if it is not suitable for the particular purpose for which it is wanted, it is impossible to obtain really good results even if the electrical apparatus is perfect. It is as in photography; if the light is unsuitable, good results cannot be obtained even with the best of lenses or plates.

All the X-ray tubes which were used up to about 1914 had a few traces of gas left, which become ionized when the E.M.F. pierces the insulating gap between cathode and anticathode, and make the tubes temporarily a conductor. Since that time tubes are being constructed which are so completely

exhausted that a discharge can no longer take place through them, unless the cathode has first been made incandescent. Wehnelt had discovered that metals which are made incandescent emit electrons. This discovery is extensively applied in the thermionic valves employed in wireless telegraphy, and Coolidge and Lilienfeld made use of it to construct the "hot cathode" tubes. The processes taking place in the treatment of these two classes of tubes are somewhat different, and it is therefore necessary to describe them separately. Pages 26 to 32 refer only to the so-called gas tubes, pages 33 and 34 only to the "hot cathode" tubes.

Gas X-ray Tubes are offered in a great variety, but the most important features are almost alike in all of them. The cathode, to be connected with the negative pole, consists of a concave mirror of aluminium, because this is the metal which disintegrates least in producing the cathode rays. The "anticathode," to be connected with the positive pole, must consist of a metal of high atomic weight and specific gravity to arrest the cathode rays suddenly, and of a very high melting point. Only platinum, iridium, tantallum or tungsten fulfil these conditions. A disc of one of these metals is either soldered to a block of copper or similar metal conducting the heat well, or else the back of the anticathode must be in touch with water, so that the great heat caused by the impact of the cathode rays can be carried off and dissipated.

This is more difficult if the anticathode is exactly in the focus of the cathode, as the rays then converge in a sharp point and the heat may become so great there that even tungsten will melt and a little cavity be formed in the surface of the anticathode. But if it is placed a little inside the focus, so that the cathode rays are spread over a circle of a few mm. in diameter, the heat is more evenly distributed and the surface remains smooth. For therapeutic purposes it is not necessary to have a sharp focus, and a blunt one of about 5 mm. diam. is therefore invariably preferred, but for tubes intended for diagnostic purposes a fairly sharp focus is necessary. It should not exceed 1 mm. in diameter, otherwise the outlines of the shadows will become blurred. For some purposes, for instance for examining fractures, or for finding foreign bodies like bullets, this would not matter much, but finer details disappear if the outlines are not sharp.

There is a third electrode, the anode, which again consists of aluminium. It is necessary only during the process of evacuation and is not required any more afterwards, but it is some advantage to connect it with the anticathode with a thin wire. In the illustration on page 1, the cathode rays are indicated by dotted lines and the X rays starting from the anticathode by lines fully drawn out.

Changes taking place in the Gas Tubes.—It has already been mentioned that the quality of the rays, i.e., the penetrating power, depends partly on the degree of evacuation. This does not remain constant. The currents discharging through the tubes produce changes which influence and vary the gas pressure. If the current used is strong enough to heat the anticathode considerably, gases which are embedded in the pores of the metal become

berated, they increase the quantity of gas in the tube, thus making the tter softer. If the anticathode used consists only of a thin disc of metal, in water-cooled tubes, or if the gases embedded normally in metals have en purposely expelled by making the anticathodes incandescent for some me during the process of evacuation, there is not much risk that the tubes ill become softer; but *new* tubes containing much metal which is still full the normal amount of gases contained in metals have a great tendency to come softer, and with such tubes prolonged exposures, or short exposures ith very strong currents, should be avoided. If serious mistakes are made this respect, the tubes may become so soft that they show a purple colour id are useless. Such tubes have to be re-exhausted before they can be ed again.

After some exposures with moderate currents, the tubes will gradually come fit to stand stronger currents and longer exposures. They can be seasoned" to stand strong currents by connecting them repeatedly at tervals for a few minutes with a moderate current, which must not be so rong as to make the tube softer. With some patience tubes can thus be ained to stand currents of 20 M.A. for over thirty seconds at a stretch ithout suffering harm.

If the anticathode has been raised to a high temperature during or before e process of evacuation, the tubes have no tendency to become softer even ith fairly strong currents.

Prevention of Excessive Heat.—As the penetrating power of the X rays, hich should remain constant, is influenced by changes in the temperature the tube, we must endeavour to prevent the accumulation of heat in the ticathode. This can be achieved in various ways. For tubes which are tended for diagnostic purposes, the disc of platinum is soldered on to a avy block of copper or other metal conducting the heat well, which is stened to a metal cylinder. This arrangement is sufficient to dissipate the at caused by a current of 300 M.A. seconds, which is about the maximum er required for diagnostic exposures; most of them require less than o M.A. seconds. For stronger use, the metal cylinder is carried through e neck of the tube, and some thin metal ribs are fastened to it outside, to t as a radiator. Tubes of this kind can be used even for exposures lasting hour, as long as the strength of current used does not exceed about 3 M.A.

For the prolonged exposures for therapeutic purposes, it is best to use ater-cooled anticathodes. Discs of platinum or tungsten are sealed in the d of glass or metal tubes, which are filled with water. Up to about 1915 ld water was used for this purpose. When the exposure lasts a long time, e temperature of the water rises gradually and the penetrating power anges accordingly. To avoid this, the tubes are now made so that *boiling* ater can be used from the beginning. They are then much more constant, cause only 80 calories are required to raise the temperature of a gramme water from 20° to 100°, whereas 539 calories are necessary to convert the iling water into steam. The anticathode thus remains at a steady temperare of 100° C. A current of 2·5 M.A. can be maintained through such tubes

for many hours without any fluctuations in the penetrating power taking place. It would be wasteful to use the cathode rays to bring the water to boiling point, and hot water is therefore filled in from the beginning, or a small cylindrical electric radiator to heat the water can be introduced, which can quickly raise the temperature to boiling point.

The heat tends to make the tubes softer, but owing to another process the gases which remain become gradually less, so that the

Tubes become harder.—Some of the electrons start from the edge of the cathode, and are driven into the glass wall of the tube, others stick to the surface of the glass in consequence of static charges and attractions. These, and some fine metal particles torn from the anticathode owing to disintegration due to reverse current, combine with the remnants of the gases and occlude them, and tend to make the vacuum higher and the rays gradually harder. This process is a very slow one with well constructed tubes and electrical apparatus, but finally all tubes are bound to become too hard to be of any use. Very weak currents which do not warm the anticathode perceptibly tend to make the tubes hard prematurely. Such weak currents are not at all an economy, as many imagine, and should be avoided.

These changes become more prominent when the diameter, i.e., the cubic capacity of a tube is small; it is therefore an advantage to use tubes with bulbs of fairly large diameter; an 8-in. bulb has a cubic capacity four times as great as a 5-in. bulb. Tubes with bulbs larger than 8 in. have been tried, but have not proved to be a success, because the protecting boxes enclosing them become unwieldy and too heavy.

In tubes which are required for the very hardest rays all the time, for treating deep-seated organs, the air contained in the metals is expelled to such an extent, by making the anticathodes incandescent, that they cannot well become softer, but have a great tendency to become harder from the beginning. They are called "self-hardening tubes" and an automatic regeneration has to be used for such tubes, as will be explained later.

Normal Current.—The vacuum will remain constant if the quantity of gases which is liberated is as great as the quantity which is being used up, i.e., if the tube is worked with its "normal" current. A M.A. meter is most convenient to find out whether a tube has its correct "load." If the index of the M.A. meter has a tendency to fall, the tube is growing harder, the current used is too weak and should be increased; if the M.A. meter has a tendency to rise, the current is too strong for the present condition of the tube, it is becoming softer and the current should be reduced. If these indications of the M.A. meter are ignored, the vacuum will change and failures owing to wrong penetration and exposure will be frequent, and the lifetime of the tubes may be shortened. The normal current which each particular tube will stand should be known, and it can be written on a piece of stamp paper pasted on the neck of the tube. The latitude in the normal current and the constancy of the tubes is much greater now than it was in the early years of X-ray work.

Regeneration of the Tubes.—All gas X-ray tubes are provided with some

arrangement which allows the penetrating power to be lowered. This can be done in various ways.

First, the temperature of the anticathode can be raised slightly by forcing a strong current through the tubes for a short time.

Secondly, many tubes have a small palladium tube projecting through the neck. This metal has the peculiarity that it allows hydrogen to pass through while it is incandescent, a process which is called osmosis. The palladium tubes are heated with a small spirit or gas flame, but care must be taken not to overdo it. The flame can also be ignited from a distance, or can even be lit automatically when the tube becomes too hard. For this purpose, the burner is placed below the palladium tube, and as soon as the current falls below the definite amount for which the control has been set (say 2·5 M.A.), the movement of the pointer of a M.A. meter operates a relay which opens a tap and allows gas to pass through the burner, which is ignited by small sparks which discharge continually between the gas burner and the palladium tube. The tube becomes softer, and as soon as the current through it has increased so far that the M.A. again indicates the set amount, the gas tap is closed by the relay circuit. It works so smoothly that the greatest variations do not exceed 0·2 M.A.

Other tubes have a small cylinder attached to the bulb, containing some suitable chemicals which liberate gases when heated. Two thin wire rods are attached to the terminals of this cylinder, they can be lowered so that they come near the terminals of the cathode and anticathode; when the distance is short enough, the current prefers to discharge through this cylinder, because the resist-

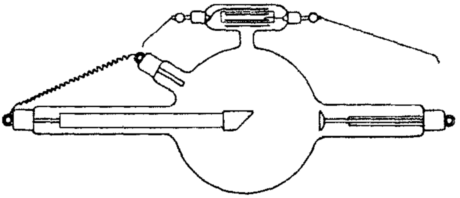


Fig. 19

ance of this path is smaller than that of the much longer gap between cathode and anticathode. The heat produced by the current liberates some gases occluded in the chemicals. The rods can also be left so that the distance between their ends and the terminals of the tube is about half the length of the equivalent spark. As soon as the tube begins to grow harder, sparks discharge between the tube neck and these rods until the vacuum has been lowered a trifle.

The Bauer air regulation is yet another method which has proved to be very good. It consists of a small disc of burned clay, sealed into a small glass tube, which projects with one end into the X-ray tube, the other end has an opening communicating with the outside air. The minute pores of the clay allow a small quantity of air to pass, but no mercury, with which it is covered. This mercury can be pushed aside temporarily by squeezing a rubber ball connected with the glass tube by means of a rubber tube. The quantity of air entering is so small that three to five short compressions of the ball may be required before the desired

degree of regeneration, which can be controlled on a fluorescent screen while the tube is working, is achieved. This kind of regeneration has stood the practical test of fifteen years' experience very well.

To make the tubes harder, a weak current can be passed through them for some 20 or 30 minutes. If this is not yet sufficient, repeat it after a rest of an hour or more. The process is sure to succeed, but tubes which are much too soft of course require greater perseverance than those in which only a little hardening is wanted. Tubes become harder fairly quickly if the current is allowed to discharge in the wrong direction, but this should never be done for reasons which will be explained under "reverse current."

Treatment of the Gas Tubes.—The tubes should be free from dust and damp, otherwise sparks may discharge outside the glass and this will occasionally lead to a perforation and destruction of a tube.

The distance between tube and electrical apparatus should not be less than 5 feet, better more. If the distance is too small, the magnetism of the iron core may deflect the cathode rays, so that the focus wanders about on the anticathode, and unsharp outlines on the negative will be the result. The tube should not be clamped too tightly in the holder, as the glass is very thin. The wires should be fastened securely, so that they cannot possibly fall out of the eyelets of the tube, for a very severe nasty shock would be the result to patient or operator if a wire became free, and in swinging about came in contact with the patient, or couch, tube stand, etc. It is best to lead the wires from the electrical apparatus along the ceiling on suitable insulators, and then vertically down to the tube. If they have to be stretched horizontally from the coil to the tube, they should be at least 6½ feet above the ground, so that nobody moving about in the room while it is dark can come in contact with a wire. Lack of care in this point might result in a dangerous spark or even the destruction of the tube. The wires from the terminals of the electric apparatus must be connected so that the pointed electrode or positive pole is connected with the anticathode, the plate with the cathode, so that the current passes through the tube in the correct direction

The space behind the anticathode should remain dark. There should be no flickering. This is caused as a rule by misfires in the interrupter, due to unsuitable self-induction, too high a frequency, or too short a duration of the contact for the primary voltage used. An insufficient quantity of mercury or dirty mercury may be the cause too. There should be ***a sharp division between the luminous and the dark half of the tube*** and no fluorescent rings in the dark part (they are due to reverse current). As long as the current used is too weak for the particular tube, there is no sharp division, and neither the M.A. meter nor the ampèremeter in the primary circuit come to rest, as the tube is gradually becoming harder. To correct this, some resistance has to be cut out on the switchboard or the frequency and the duration of contact in the interrupter have to be increased.

If the current used is too strong, the tube shows a very bright green light, and the anticathode has a tendency to become incandescent. To prevent this more resistance has to be inserted or the frequency of the inter-

With a good tube, the normal current may be exceeded for instantaneous exposures even a 100 times, or about 10 times for exposures lasting no more than ten seconds, without fear of injuring the tube, but if it is exceeded for exposures of long duration, the tube is likely to become soft, or even useless if this continues for too long.

When a tube is removed from the stand while it is yet warm, it should not be laid on a cold surface. It is best to suspend the tubes in brackets fixed on the wall at such a height that the lowest ends of the tubes are fully 6 feet above the ground.

It is a bad economy to have only one tube, because if all exposures are attempted with one tube only, either the quality of many negatives will be poor or else the vacuum has to be altered frequently to adapt the tube to thin or thick parts of the body. This means not only waste of the lifetime of the tubes, but a loss of time for the operator. It is more economical to have about four tubes in use to suit various parts of the body: a soft one for hands, arms, etc., two medium ones for head, chest, kidneys, etc., and a hard one for the pelvis or for therapeutic exposures.

In this respect, Coolidge tubes are better, because the degree of penetration is controlled entirely by the strength of the current heating the cathode.

If treated with reasonable care, good modern tubes will have a lifetime of some 500 working hours. With carelessness, or want of skill, even the best tubes may, however, be destroyed in a short time. The tubes have to be protected from

Reverse Current, as this deteriorates the quality of the negatives and reduces the lifetime of the tubes considerably. With well constructed coils, the currents most frequently used for diagnostic exposures, 2·5 to 6 or even 10 M.A., can be obtained free from reverse current, but if strong currents above 10 M.A. are used, it begins to appear. (See *Plate II* facing page 7, and page 32.)

Spark Gaps or Valve Tubes have then to be inserted. The effect which they have on reducing the reverse current is apparent from the illustrations on *Plate II*. The spark gaps used for this purpose consist of a plate and a point, enclosed in a glass tube; the length of the gap between them can easily be altered. The sparks have a great repugnance to discharging while the point is the negative pole. When attached to the discharging pillars of a spark coil, they offer a great resistance to any reverse current, whereas they weaken the currents discharging in the right direction to a small extent only. The spark gaps cannot be used for strong currents, because they do not rectify any more when a flame-like arc is formed. In such cases valve tubes are better. In these, the electric repulsion is utilized to suppress or reduce the reverse current. The outer cylinder has to be connected with the negative pole of the spark coil, the inner one with the cathode of the tube. The valve tube may be suspended near the coil, but the distance between it and the X-ray tube should not be less than about 5 feet. The equivalent spark of the valve tubes should be about 2 cm. Most of them are provided with osmotic regeneration.

Spark gaps or valve tubes increase the resistance of the secondary circuit. The initial E.M.F. must therefore rise a trifle higher to overcome it, but the X rays become a little softer because some of the E.M.F. is absorbed and the intensity is a little weakened by this additional resistance. The light of the sparks and the fluorescent light of the valve tubes is inconvenient when the room should be dark for examination on the fluorescent screen. It is therefore desirable that these valves can easily be switched off or on without having even to stop the apparatus. With the spark gap, this can be done by merely screwing home the point so that it touches the plate. For valve tubes, a bipolar high-tension change-over switch has been constructed, so that by pulling a silk cord on one side the valve tube can be switched on; by pulling a cord on the other side, it can be switched off.

Oscilloscope Tubes.—The presence or absence of reverse current can be proved best by an oscilloscope tube. This consists of a glass cylinder, 6 to 9 in. long, closed at both ends, into which two aluminium wires are sealed with only a small gap between them. The tube has to be evacuated to a certain degree. As long as the current discharges in one direction only, the wire connected with the negative pole shows a purple fluorescence, and the *length of the fluorescent band is in proportion to the strength of the current used.*

Fig. 20.

Of the second wire, only the point shows a faint light. But if each wire becomes alternately the positive or negative pole, as will be the case when reverse current appears, both aluminium wires will become fluorescent alternately. The illustrations show the appearance of oscilloscope tubes under various conditions. The length of the fluorescent band pointing *upwards* is in proportion to the intensity of the single discharges of the breaking current which are being used to produce the X rays. The length of the fluorescent bands pointing *downwards* indicate the intensity of the closing or reverse current, which is the chief cause of the tubes becoming gradually so hard that they cannot be used any more (see *Plate II*).

Fig. I was obtained with a wrongly-constructed coil. The intensity of the reverse current is nearly as great as the intensity of the breaking current. 1680 watts had to be used in the primary circuit to obtain this discharge. The number of milliampères could not be measured on account of the large percentage of reverse current.

Figures II, III, IV, and V were taken with a 16-in. coil as made in 1912.

Fig. II.—600 watts only were used in the primary coil. The fluorescent band produced by the breaking current is a little longer than that obtained in Fig. I, in spite of the fact that the primary current had only one third of the strength of that used for Fig. I. The M.A. meter registered 5 M.A. *No valve of any kind* was used in the secondary circuit, nevertheless the reverse current is practically nil. (The *point* of the wire connected with the positive pole becomes luminous even if no reverse current is present.)

Fig. III.—2000 watts were used in the primary circuit, the M.A. meter registered 15 M.A. *No valve of any kind* was used. Reverse current just begins to appear.

Fig. IV.—3500 watts were used in the primary, no valve of any kind in the secondary circuit. The M.A. meter gives no correct information on account of the heavy reverse current, indicated by the fluorescent band pointing downwards.

Fig. V.—This has been taken under exactly the same conditions as No. IV, but a spark gap was inserted in the secondary circuit, and reduced the reverse current very much. The M.A. meter indicated 18 M.A. The length of the fluorescent band produced by the breaking of the primary current is reduced a little too, because a valve increases the resistance of the circuit, and is therefore bound to weaken somewhat the intensity of the X rays.

Fig. VI has been taken with a much larger coil, as used for exposures with one single flash. Nearly 5000 watts were used in the primary coil, a valve tube was inserted in the secondary circuit; 30 M.A. were registered by the M.A. meter.

The illustrations show the fluorescent bands in about half their actual size. A mercury interrupter, a 240 volt supply, and an X-ray tube with an equivalent spark of 12 cm. were used for all the experiments.

The illustrations prove that as long as 6 M.A. were not exceeded no valves were required with good spark coils as made in 1912. With currents of from 6 to about 15 M.A. a spark gap is sufficient to suppress the small amount of reverse current. For currents exceeding 16 M.A. a valve tube is best. Considerable progress has been made in the construction of spark coils in the twelve years since these experiments were made, so that currents of even greater intensity can be obtained now free from reverse currents, and valves are nowadays required only for therapeutic exposures, to make the X rays a little more homogeneous by increasing the resistance of the scondary circuit.

As the oscilloscope tubes are not expensive, but very useful as a control, it is desirable to have them in all installations, and they can easily be fixed on a small board which at the same time carries the M.A. meter and possibly a spark gap.

Hot Cathode Tubes.—These tubes are exhausted so far, that practically no gases remain, and no current can discharge through them until the cathode is made incandescent. This can be done when it is formed of a suitable wire, which can be heated by connecting its ends to an accumulator, or small transformer, supplying a current of about 12 volts and 3 to 5 ampères. This source of electricity has to be insulated carefully from earth. When the cathode is made incandescent, electrons can be propelled from it, and currents of some 10,000 volts are then able to discharge through the tube. The penetrating power of the X rays produced depends on the E.M.F. of the current used, and the intensity, i.e., the number of M.A., depends on the temperature to which the cathode has been raised. This temperature, however, also slightly influences the penetrating power.

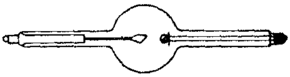


Fig. 21.

It is a great convenience that the penetrating power and the number of M.A. or intensity can be varied *independently* of one another, and on this account the hot cathode tubes would be sure to supersede the gas tubes entirely, if the latter had not two advantages which the hot cathode tubes

do not possess. The Coolidge tubes, have not yet quite a sharp focus, owing to the construction of the cathode, which consists of a spiral of tungsten wire. Though this does not matter for examining fractures, large foreign bodies like bullets, etc., it is not possible to obtain negatives showing the finest details which can be produced with tubes in which the cathode rays can be made to converge in a *sharp* focus. The Lilienfeld tube has a sharp focus, but with this kind of tube a second auxiliary circuit—three different circuits altogether—becomes necessary, which makes the installation and the working a little complicated. About twice as many M.A. are required to produce a certain intensity with the hot cathode tubes as with gas tubes.

For therapeutic exposures, the blunt focus does not matter, and the Coolidge tubes are largely used for the treatment of skin diseases. The bundle of X rays obtained from them is, however, softer than that obtained from very hard gas tubes, the latter emit a higher percentage of hard rays, because a high initial voltage is necessary to pierce the insulation before each single discharge can begin, whereas with the hot cathode tubes the path for the discharge is prepared already by the electrons emitted by the incandescent cathodes. The consequence is that with the same apparatus and primary current, the percentage of hard rays produced will be smaller with a Coolidge tube than with a gas tube, a somewhat thicker filter has to be used to make the rays from a hot cathode tube " homogeneous " to the same extent as when a gas tube is being used, and the thicker filter makes somewhat longer exposures necessary. The filament of the hot cathode tubes wears out gradually, like that of incandescent lamps, and their lifetime is not any longer than that of good gas tubes.

Diaphragm.—A few cathode rays start from the edge of the cathode, and are not propelled in the direction of the anticathode, but are converted into X rays on striking the glass wall of the tube. Any reverse current which may reach the tube also causes the appearance of X rays on various parts of the glass. All those rays which do not emanate from the focus of the anticathode, and the scattered rays, which have been mentioned on page 9, are projected in various directions. They are a great nuisance for diagnostic purposes, because they reduce the sharpness of the outlines and make diagnosis in some cases impossible.

The quantity of the scattered rays increases with the diameter of the cone of X rays used; partly for this reason, and partly to protect the body from a superfluous dose of the X rays, which act like an irritant poison, it is desirable not to expose a larger area than is necessary. The diameter of the cone of rays reaching the body should not be larger than is just necessary to include the parts we wish to examine. All other parts have to be protected carefully from the influence of the rays.

This protection can be achieved by placing a diaphragm of metal of sufficient density between the tube and the patient. The diameter of the cone of rays reaching the patient varies with the aperture of the diaphragm, and with the distance between it and the body of the patient. For diagnostic purposes, the area covered should have such a size that it will just about

cover the photographic plate used. For therapeutic exposures, the cone of rays must be chosen so large that the organ to be treated is sure to be included even if its exact position cannot be ascertained quite accurately.

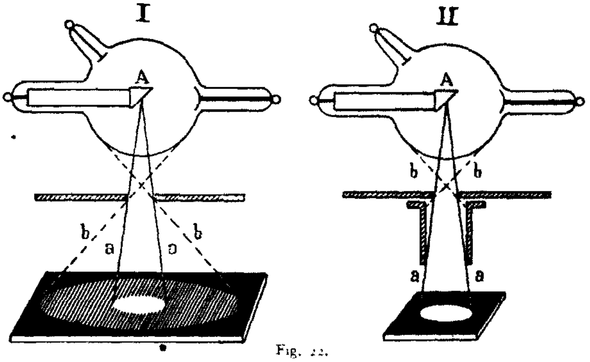


Fig. 22.

Flat diaphragms are usually attached to the boxes enclosing the tubes whereby the distance between anticathode and diaphragm remains unaltered. Diaphragms with holes of 2 to 8 cm. diameter should be available, or else a rectangular diaphragm in which the size of the opening can be varied.

In diagnostic work it is a great advantage for a large number of exposures to use cylinder diaphragms 15 cm. long and 12 cm. wide, in addition to the flat diaphragms. The sketches show that with a cylinder diaphragm rays emanating from the glass walls of the tube are more efficiently prevented from reaching the photographic plate than when a flat diaphragm only is used (see Fig. 22). The cylinder also serves very well as a compressor.

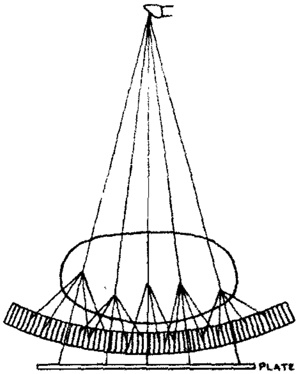


Fig. 23.

The Potter Bucky Diaphragm.—A further diaphragm has been invented to eliminate the effects of those rays which are scattered in all directions in passing through the body. It consists of strips of lead built up between strips of wood or wax in such a way that they are radial to the rays. The lead strips thus cut off a small portion only of the

rays which come direct from the anticathode, but they cut off entirely the rays which are scattered by the body (see Fig. 23). The grid in which the lead and wood strips are mounted is kept moving by clockwork so that no shadows of the strips are cast.

MEASURING THE X RAYS. DOSAGE.

When we wish to profit by the experiences which others have gained, or to repeat the results which we obtained previously, or to communicate them to others, it is essential that the quality and intensity of the X rays which produce certain effects can be measured and described so that the same conditions can be repeated.

The effect produced by the rays is in proportion to the quantity of the X rays which has been absorbed, and this depends on :—

1. The quality of the rays used and the specific gravity of the object ; the greater the penetrating power and the smaller the specific gravity, the smaller will be the quantity which is absorbed.
2. The intensity of the rays reaching the object. This varies with the intensity of the rays produced in the tube and the losses they sustain on the way owing to the distance and owing to absorption in the media they have to traverse before they reach the object.
3. The length of time the rays are allowed to act.

The duration of an exposure required to produce a certain effect therefore varies with the intensity and the quality of the rays available, and the distance between the tube and object. Tables showing the influence of the distance on the necessary duration of the exposure will be found on page 127.

We cannot yet utilize the units of centimetre, gramme and second as standards wherewith to compare the intensity of the X rays, and they cannot be measured quite so easily and accurately as, for instance, heat or light, etc., because they are not noticeable to our senses, and there are no substances known in which the rays produce visible changes sufficiently great that small differences could be noticed immediately. They do, however, produce some physical, chemical and biological changes, which can be utilized for measuring their intensity. As these methods become more accurate, and more universally known, the successes which can be obtained with X rays will increase and the failures will gradually diminish.

Milliampère Meters are now being used in almost all installations as a convenient and reliable help to give some information about the intensity of the X rays generated in the tube, but it must be borne in mind that the intensity depends on both volts and milliampères discharging through the tube. Statements that a certain number of milliampères have been used do not give any information about the intensity of the X rays produced, unless the wave length or the length of the equivalent spark or the E.M.F. with

which they have been obtained is known too. How the wave length or quality of the rays can be measured will be described presently.

With a current of 5 M.A. the intensity of the X rays produced is just twice as great as with a current of 2·5 M.A. only, provided that the E.M.F. of the current used and the degree of evacuation of the tube are the same. This will be the case when the number of M.A. is varied by varying the frequency of the interruptions. With some interrupters it is possible to use either two or four interruptions per revolution and the intensity of the X rays will be exactly twice as great with four as with two interruptions. The frequency can also be varied by varying the speed of the motor.

The conditions are different if the number of M.A. is varied by varying the strength of the current used in the primary circuit. In such a case the increase or decrease is due to an increase or decrease in the E.M.F. used on the terminals of the tube, and if the number of M.A. is increased in this way from 2·5 to 5 M.A., the intensity with the latter current will be more than three times as great as with the former.

With a current of 2·5 M.A. through a tube whose equivalent spark is 15 cm. the intensity will therefore be much greater than with the same strength of current through a tube with an equivalent spark of 5 cm. only, because in the latter case a much lower E.M.F. is sufficient to produce the 2·5 M.A. than is necessary with the harder tube. See table on page 129.

It is somewhat surprising that M.A. meters can be used for measuring intermittent currents. They do not measure the actual strength of the impulses used, but indicate only *the mean value between the actual strength of each impulse, and the number of discharges in unit time.*

The position of the pointer is determined by the parallelogram of forces. Along A C is measured the maximum value of each impulse, and along A F the time which elapses between two succeeding impulses, i.e., during which no current flows in the M.A. meter. *Fifty intense discharges per second produce the same deflection of the pointer as* 100 *discharges of half the intensity.* It is a decided advantage that this is so, because 50 intense flashes of X rays produce the same biological or chemical effects as 100 flashes of half the intensity. If the M.A. meters were to indicate the maximum of each single discharge, without regard to frequency, as for instance the oscilloscope tubes do, it would become necessary to measure the *number* of discharges also. This would be an additional complication with some interrupters, and would be impossible with others. As the M.A. meters indicate a mean value, we have only to measure the quality, the number of M.A., and the number of seconds or minutes during which the object is exposed to the rays.

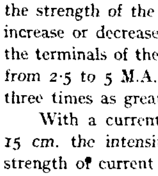


Fig. 24.

It is worth mentioning that the ampèremeters which are used in the primary circuits of spark coils also indicate only a mean value between the actual strength of the current and the frequency of the interruptions.

The same applies to the "kilo volt meters" which are now frequently employed in the primary circuit. They can be calibrated so that they indicate the voltage for a certain frequency fairly accurately, but when this changes, the indications of these instruments become wrong.

The number of milliampère seconds or minutes (5 M.A. for 20 seconds are called 100 M.A. seconds) have been found empirically which are necessary

to give a correctly exposed negative with a given penetrating power, distance between tube and plate, and thickness or density of the object. A table showing the number of M.A. seconds required for various parts of the body will be found on pages 68 and 129. Many hundred thousand exposures have been timed correctly by making use of the milliampère-second product.

The table will be found correct when spark coils and gas tubes are used. With the interrupterless high-tension transformers the number of M.A. seconds has to be larger; the reason for this has already been explained. When Coolidge tubes are being used instead of gas tubes the number of milliampères has to be doubled.

The indications of the M.A. meter will become inaccurate when reverse current can discharge through the tube. The pointers of the M.A. meters of the moving coil type do not deflect at all when waves of an alternating current pass through such instruments. When reverse currents reach instruments of this type, they indicate the *difference between the strength of the closing and the breaking current*, the stronger the reverse current, the smaller will be the deflection of the pointer.

For the long exposures required when X rays are used for therapeutic purposes it has also to be remembered that the hardness of the tube and the number of M.A. discharging through it determine the intensity of the rays *produced in the tube*. The intensity of the rays reaching the objects is much smaller, owing to the losses which are caused by the increasing distance and by absorption. The former can easily be found out by calculation, but if the rays have to traverse filters or thicker parts of the human body, calculation becomes impossible, because slight differences in the quality of the rays and the influence of the scattered rays alter the intensity and the dose of the rays too much, especially if exposures of long duration are required. The intensity reaching deep-seated objects has therefore to be found out with the help of the tables on pages 134 and 135, or empirically for various apparatus, tubes, filters, diaphragms and depths of the body. How this can be done will be explained later on.

Even in those cases where the M.A. meter is not required for determining the duration of the exposure, it is most convenient to have one, because even a slight alteration in the condition of the tube is indicated by it. When the tube becomes softer, the number of M.A. increases, when it becomes harder, it diminishes. A M.A. meter should therefore be used in every installation.

Methods of measuring the Quality of the X rays.—After some experience, a mere glance at a tube will tell us whether it is soft, medium or hard. In soft tubes some bluish or purple light is visible near the anode; medium tubes look as if the space between cathode and anticathode were filled with air of green colour. With hard tubes, only the glass walls of the luminous half show a thin, pale green colour. With very hard tubes, brush discharges produce a crackling noise and smell of ozone.

A simple and quick way of ascertaining the quality of the rays approximately is to hold one's hand for a moment between the tubes and a fluorescent screen. The different appearance of the bones (see illustrations on

Plate I) gives information whether the rays are soft, medium, hard, etc. This experiment should not, however, be repeated too often, for fear of injuring the skin. Whenever the X rays are to be used frequently, it is advisable to use a skeleton hand embedded in wax in a glove, and to hold this between the tube and the screen. *Another simple control is the*

Equivalent Spark Gap.—This has already been partly described on page 5. The figures *given in the following pages* refer to sparks *discharging* between a blunt point and a plate in such a way that the point is the positive pole. When spheres are used instead of point and plate, the figures will be quite different, and will vary with the diameter of the spheres. Tables about this will be found on pages 126, 127, and 129.

A tube is very soft if the equivalent spark is 3 to 6 cm. long, soft when it is 7 to 10, medium when it is 10 to 15, and hard when it is 20 cm. or more. The hardest tubes used nowadays have equivalent sparks of about 40 cm. The length of the equivalent spark varies, however, with the strength of the current used and with the frequency of the interrupter and the type of apparatus. With one and the same tube, it may be 10 cm. while a current of 1 M.A. is used, but will *increase to* 18·5 cm. when *the strength of the current* has been raised to 10 M.A. *without any change taking place in the vacuum* (see table 9 on page 129). This is as it should be if the strength of current passing through a given tube has been increased by raising the strength of the current in the primary and thereby the E.M.F. which is sending the current through the tube. There is also a considerable difference in the length of the equivalent spark of the *same* tube, according to whether we connect it with a spark coil or with an alternating current transformer; it is considerably shorter with the latter. The length of the equivalent spark gap does not therefore convey *any accurate information about the degree of evacuation of a gas tube or the* temperature of the cathode of a Coolidge tube, unless the shape and diameter *of the electrodes used on the discharging* pillars, *the kind of* apparatus (spark coil or alternating current transformer), and the number of M.A. used while it was being measured, are stated too. When this is done, it gives us a rough idea of the E.M.F. at which the current is passing through the tube used and therefore of the quality of the rays. The information is not accurate or absolute, but it serves as a guide especially as to changes which may be going on while the tube is being used.

The **Bauer Qualimeter** is a static voltmeter, to be connected with the cathode. It has some defects similar to those of the equivalent spark; while it is connected with one and the same tube, the position of the pointer varies with the frequency of the interrupter. The instrument is useless as a standard for comparison between various tubes on different apparatus, but while connected with a certain apparatus and tube, a glance at the scale will show whether the tube is soft, medium or hard, and whether it is constant or is becoming softer or harder during an exposure. As this can be seen equally well from the scale of the M.A. meter, there is no real need for this instrument.

Benoist, Wehnelt and others constructed penetrometers, in which the

transparency of a thin disc or strip of silver is used for comparison. Silver was supposed for a long time to have the peculiarity that the degree of its transparency is less affected by the quality of the rays than that of other metals, for instance, aluminium. This has proved to be an error which arose because the "selective absorption" of the metals was not yet known, and that of silver happens to coincide with the wave lengths which are used most frequently for diagnostic purposes. The selective absorption of silver begins with wave length 0·485. The degree of luminosity of a fluorescent screen placed behind a thin disc of silver does not therefore vary very much whether soft or hard rays are being used, whereas the luminosity of a screen placed behind aluminium varies considerably with the quality of the rays and the thickness of the aluminium used.

In the Benoist penetrometer a thin disc of silver, 16 mm. in diameter and 0·11 mm. thick, is surrounded by 12 steps of aluminium of increasing thickness: the first step is 1 mm. and the last 12 mm. thick. When this is placed behind a fluorescent screen, the luminosity of the circle covered by the silver was intended as a sort of standard candle, and we have to look for that part of the screen covered by the aluminium steps which shows a similar degree of luminosity as the circle covered by the silver. If the tube to be tested is soft, step No. 2 or 3; if it is hard, step No. 7 or 8 may show the same degree of fluorescence as the area covered by the silver. We say then that the penetrating power of the tube is No. 3 or No. 7, etc., Benoist.

To compare the efficiency of various coils, interrupters, intensifying screens, etc., I have found it more convenient to arrange the aluminium steps in a straight line instead of a circle. The thickness of the steps rises in a geometrical progression, and has been chosen so that step No. 2 requires 1·5 times as long an exposure to reach the same density on a negative as No. 1, or step No. 4 2·25 times as long an exposure as No. 2. If paper prints are made, they can be shifted till we find which densities coincide. We can thus find out comparatively small differences which exist in the intensities of the X rays produced with various apparatus. To make such comparisons, the strength of current used in the primary circuit, the duration of the exposure, the composition of the developer and the duration of the development must be exactly alike.

The Wehnelt penetrometer is a modification of the Benoist instrument. Formerly, one-half of a small fluorescent screen was covered by a thin sheet of silver, a wedge of aluminium 16 cm. long and increasing in thickness from 1 to 11 mm. could be moved by rack and pinion behind the other half of the screen, till the position was found in which the two fields of the screen showed similar luminosity. A scale then indicated the number of "Wehnelt" units of the tube. In its latest shape the gradually increasing wedge has been abandoned, and replaced by steps of increasing thickness. The operator can examine the picture in a mirror, so that his eyes cannot be reached by X rays.

Penetrometers of this kind really measure the *intensity* of the X rays. If we examine a tube while say 2 M.A. are used, the Wehnelt penetrometer may indicate 4, for instance, but when the current is raised to 5 M.A. by increasing the primary current, it will indicate 6 degrees, in spite of the fact that the vacuum of the tube has not been altered. This is as it should

be, because, as has been explained already on pages 5 and 37, under such conditions a higher E.M.F. is used, and harder rays are generated. But when we increase the frequency of the interrupter or use a shorter distance between anticathode and the penetrometer, the relation between the transparency of the silver and that of the aluminium changes too and gives another reading, although in these two instances the quality of the rays remained unchanged and only the intensity has been increased.

Instruments of this kind are therefore useful for comparing the penetrating powers of various tubes *only when the same frequency, strength of current and the same distance between anticathode and penetrometer are used in each case.* Though it would be possible to do this, they have never been quite satisfactory, and are gradually becoming obsolete. They are unsuitable for measuring very hard rays.

Instruments with which the quality of the X rays can be measured accurately and easily are, however, a necessity. It has to be remembered that any excess or deficiency in the penetrating power used must affect the result unfavourably.

For diagnostic exposures, the penetrating power used determines whether the part of the body to be examined can become sufficiently transparent to enable us to detect the shadows due to different densities of various internal organs ; but an unnecessary excess of penetrating power makes the finer details disappear. For therapeutic exposures, the penetrating power used must be so great that the supervening tissues do not weaken the rays intended for organs deeper down too much by absorption, but if this degree should be exceeded, the organs for which the rays are intended will absorb less too, and the exposure has to be needlessly prolonged. The biological effect of the rays becomes smaller as their penetrating power increases.

The quality of the X rays can be measured reasonably accurately with the **Absorption Meter** suggested by the late Dr. Christen. It is based on the idea that the intensity of the rays is diminished by absorption and that the degree of the diminution depends on the *thickness* of a given material and on the *penetrating power or quality* of the X rays used. So far the idea does not differ from that of the Benoist or Wehnelt penetrometers, but instead of using the transparency of silver for comparison, Christen suggests measuring the *thickness* of water or aluminium or any other convenient material which will *reduce the intensity of the rays to one-half by absorption.*

To find out this point, the intensity of the X rays reaching the field for comparison must be reduced to one-half by some other method, and this can be done easily in various ways. For instance, a piece of lead, 1 cm. square and about 1·5 mm. thick can be perforated by holes, the number and diameter of which is chosen so that the total area of the holes is just 0·5 cm². (16 holes of 2 mm. diameter each would, for instance, fulfil this condition). One-half of the X rays reaching this lead grating is absorbed by the lead. If a fluorescent screen is held about 2 cm. behind this grating, the holes are no longer separately visible, and the screen appears evenly illuminated, but with half

the intensity only of the rays falling on the lead grating. In another yet simpler instrument, a strip of lead, not less than 2 mm. thick and about 2 cm. wide and 10 cm. long may be placed on a photographic plate, and immediately adjoining are placed the aluminium steps to be mentioned presently. When the lead is removed after an exposure of say 15 seconds has been given, and the exposure is then continued for another 15 seconds,

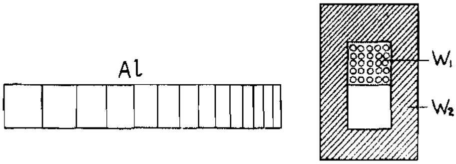


Fig. 25.

the part of the plate covered by the lead during half the exposure received just half the intensity of the X rays which reached the aluminium.

The thickness of water, or aluminium, or any other convenient material which will reduce the intensity of the rays to one-half, is bound to vary. It must *increase* as the wave length of the rays used *diminishes*, i.e., as the penetrating power increases, and the *thickness required to reduce the intensity of the rays to one-half will be an accurate definition of the quality of the rays used.*

In some of the absorption meters, a wedge consisting of about 12 steps of bakelite—a resin made from coal tar, which happens to have exactly the

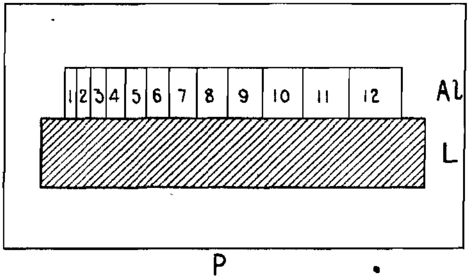


Fig. 26.

ıme opacity as water, and very nearly the same as the soft tissues of the uman body—is used. The steps increase in thickness by 5 mm. at a time, ut instead of saying that so-and-so many mm. of bakelite reduce the intensity) one-half, the result is always expressed in mm. of water. In other instruıents, aluminium steps, increasing in thickness from 0·5 to 1, 1·5, 2, 3, 4, :c., mm. are used, and the results are given in terms of so-and-so many mm.

of aluminium which are required to reduce the intensity of the rays to one-half.

The ladders of bakelite or aluminium are placed so that they immediately adjoin that part of the screen or plate which is covered by the lead grating, and it is easy to ascertain which part of the fluorescent screen or negative shows the same luminosity, or the same degree of density, as the area which is subjected to only one-half of the X rays falling on the steps. The thickness of water or of aluminium which is necessary to reduce the intensity of the rays to one-half by absorption is then read on a scale attached to the instrument.

It is possible also to find out the wave length of the radiation with such instruments, because the degree of absorption due to a given material depends on its thickness and on the wave length of the X rays used. The thickness (of aluminium) which will reduce the intensity to one-half by absorption is therefore a direct measure of the wave length used. The table on page 126 shows the various wave lengths in A.U. which correspond to various thicknesses of aluminium which will reduce the intensity of the rays to one-half.

This method has proved much more useful and accurate than the penetrometers using the transparency of silver for comparison. The absorption meters are, however, sure to be superseded gradually by the spectrometers, because the latter enable us to measure the wave lengths emitted by individual tubes under various conditions directly in "A" units easily and accurately. But as a spectrometer costs almost as many pounds as the simplest absorption meter costs shillings, the latter will be useful to many medical men as long as a spectrometer is not available.

Spectrometers enable us to measure the wave length directly. By passing X rays through crystals, v. Laue discovered that the interference phenomena known from ordinary light became apparent with X rays too, and thus he proved beyond doubt that they consist of waves similar to those of ordinary light only very much shorter. The full development and application of the discovery was effected by Sir William Bragg and his son Prof. Bragg. The spectrometers used by these physicists are, however, too complicated for medical purposes. Exposures of several hours' duration are necessary to find a single wave length, but Drs. Staunig, March and Fritz of Innsbruck have succeeded in modifying the instrument so that the whole spectrum of the X rays can be examined on a fluorescent screen.

With a new modification, the exact position of the fluorescent lines can also be recorded on a strip of bromide of silver paper. This is an improvement, because it increases the accuracy of the method when the shortest waves, produced with 200,000 to 250,000 volts have to be measured. When the spectrum lines produced by waves of 0·06 or 0·07 A.U. are recorded on photographic paper, the greatest error does not exceed more than ± 0·001 of an A.U. unit.

The spectrum of X rays from a tube has a sharp and well-defined boundary at its short wave length end. March has shown that the energy

distribution through such a spectrum is always the same, that is to say, that the wave length at which the maximum intensity occurs bears a definite relation to the boundary wave length (denoted by λ_0) and that this relation can only be varied by filters. Consequently, the value of the boundary wave-length λ_0 characterizes the quality of the beam of X rays entirely.

The March spectrometer is so arranged that the value of λ_0, the boundary wave, can be read directly off a scale in Ängström units. The use of the instrument is simple and can be carried out by a novice after a few minutes' instruction. A separate publication deals with it in detail.

It is an undoubted advance in theory and practice that the quality of the rays can thus be found out easily and accurately and quite independently of the quantity or intensity of the rays. Tubes can be tested and the wave lengths obtained under various conditions with each individual tube can be noted in a book or on a card system.

The various wave lengths which have been found best for diagnosis for various thicknesses and parts of the body, will be found in tables Nos. 10 and 11, page 130. It is not claimed that with the help of these tables negatives can be produced which will be superior to the best which have been produced so far, but it is claimed that the *average* quality will be *greatly improved* if rays of the correct penetrating power only are employed. Failures can be avoided and in difficult cases the diagnostic value will become much more reliable, for not only will the existence of a small stone or tumour, etc., be shown on the plate, but the *absence* of such shadow on the negative will be a more positive proof that the suspected disease does not exist than is often the case at present.

For therapeutic exposures, the spectrometer enables us to find the percentage of the surface dose which will reach various depths when various qualities of the rays, focus skin distances, apertures of windows and filters are being used. A few tables (see No. 22 on page 136 and on a special pamphlet) help to find the depth dose quickly and accurately without the somewhat lengthy and tedious exposures on phantoms described on pages 54–56 being required.

The spectrometer helps also to find the actual number of volts used in a tube. Einstein expected from theoretical reflections that there must be a relation between the shortest wave length and the number of volts discharging through a tube. The experiments of Duane and Hunt proved that this is so, and that the value of the boundary line of the shortest wave length is in inverse proportion to the voltage used. The number of kilo volts available on the terminals of the tube can be found out, if the figure 12·358 is divided by the value of this shortest wave length. If the spectrometer should, for instance, indicate this to be $\lambda_0 = 0{\cdot}12$, the formula to find the number of kilo volts will be $\frac{12{\cdot}358}{0{\cdot}12} = 103{\cdot}5$ K.V.

It is thus possible to find the E.M.F. prevailing *on the terminals of the tube while a current is flowing*. The value of the E.M.F. thus obtained differs

from, and is much more important than, that given by the equivalent spark gap. The latter measures the voltage immediately before an impulse discharges—i.e., on *open circuit*. It cannot therefore give an absolute measure of the voltage which is actually driving current through the tube, and to calibrate the equivalent spark gaps in Angström units, as has been done, is entirely inaccurate.

When the *actual number of volts* discharging through the *tube on closed* circuit is known, it becomes possible to determine the efficiency of individual spark coils or transformers much more accurately than this was possible up to now.

To measure the *intensity* of the rays, chromo radiometers, Kienböck quantimeters and the ionization quantimeters are used.

In the **Chromo Radiometers** which were the first attempt to measure the quantity of X rays, chemicals are used which change their colour under the influence of the X rays. They were first suggested by Prof. Holzknecht in 1902.

Sabouraud employs for this purpose pastilles of barium platino cyanide, which changes its colour gradually from apple-green to red-brown. The tint which the pastilles will assume when they have been exposed to a dose of X rays, which causes the hairs to fall out, has been found empirically, and is called " Teinte B," and a tablet showing this colour is supplied with every booklet. These pastilles are not very sensitive, and to obtain a sufficiently great change in colour, they have to be exposed at *half the distance existing between anticathode and object*, so that they receive four times the quantity of X rays which reaches the object.

The discoloration is due to a process of dehydration. The pastilles are therefore also sensitive to a high temperature. The distance between the glass wall of the tube and the pastille must therefore be at least 2 cm., otherwise the heat of the glass bulb might help to discolour them prematurely. As ordinary daylight restores the original colour gradually, the pastilles have to be protected from it during the exposure, and have to be compared with the standard tint in a light which is weak in actinic rays, such, for instance, as the light of an incandescent lamp. The pastilles can be brought back to nearly their original colour by exposure to full daylight, but sunlight should be avoided. They can be used a second, possibly even a third time, but they leave no permanent record. The tables on page 131 show how fractions or multiples of the epilation dose can also be measured with these pastilles.

In the **Kienböck Quantimeter** strips of bromide of silver paper are used and developed after exposure. They are much more sensitive to X rays than barium platino cyanide. An epilation dose which changes the pastille to Teinte B will produce blackness on the developed bromide paper. Shades of grey between the white of the unexposed strip and the black indicate fractions of an epilation dose. The strips are exposed on the skin and the epilation dose is denoted by 10 x, and divided into ten shades. Each differs

from its neighbour by 1 x. Thus 10 x on the Kienböck scale is equivalent to 1 B on the Sabouraud scale. The dose, which produces an erythema on the skin as distinct from the mere falling out of hair, is 12 x. The strips have the further great advantage that they leave a permanent record and can be pasted in a case book.

The black tint of 10 x on the scale is, however, not convenient, partly because there is no indication whether it has just been reached or whether it has been exceeded already, and partly because the differences between the tints of 8, 9 and 10 x are small, so that it is difficult to distinguish between them. The differences between 1 and 7 are, however, great, and it is therefore advisable to rely on these only for the tests and for comparison, and this can easily be done. It is known beforehand how long approximately an exposure has to last (see table on page 133). If it is likely that with the distance, the filter and the number of milliampères used, the erythema dose will be reached in about eight minutes, the exposure should be interrupted after two minutes already to develop the Kienböck strip. If it shows a tint similar to 3 x on the scale, this would mean that one-fourth of the erythema dose has been given, and that if the exposure is continued under the same conditions for another six minutes, the full erythema dose will have been reached. If the tint should be similar to 4 x on the scale, the *total* exposure will have to last six minutes only. If used in this way, the exposures can be timed more accurately than if we attempt to rely on the tints 8 to 10 for comparison.

The only disadvantage is that the results cannot be read off until the strips have been developed for 60 seconds, in a developer of standard strength, and of a temperature of 64° F. Large but short test-tubes, or better, small porcelain trays $3\frac{1}{2} \times 2\frac{1}{2}$ in., can be used for this purpose. If these small dishes for developing, washing and fixing are arranged in a light-tight box, the development can be carried out in the room in which the exposure is being made, and the operator need not even retire to the photographic dark room.

These chromo quantimeters were invented to indicate the dose which will cause the hairs to fall out. If the time of exposure is prolonged by about 20 per cent, the inflammation and subsequent discoloration of the skin known as "erythema" will appear.

When X rays began to be used for treating skin diseases, tubes of a medium penetrating power with equivalent sparks of 8 to 10 cm. were used exclusively, and filters, if used at all, were very thin. Under such circumstances, the Teinte B or the 10 x dose represents four-fifths of the dose which will make an erythema appear on the skin later on, and tens of thousands of exposures have been timed correctly with the help of these chromo radiometers.

Hard rays and aluminium filters are used now universally even for skin diseases, and since the therapeutic applications have been extended to deeper-seated organs like the ovaries, etc., it has become necessary to use very hard rays and heavy filters. This has changed the conditions for the following reasons: The metal salts of the quantimeters, as well as the cells of the human body, are more transparent to harder rays, a smaller quantity of the latter being absorbed, but the transparency of the tissues of the *human body increases at a quicker rate than that of the metal salts* because the latter have a greater specific gravity. Whereas the tint shown at 6 x on the scale repre-

sents half the dose which will produce an erythema, as long as rays of medium penetrating power and no filter are being used, the *same* tint represents only a fourth part or even less of the erythema dose when hard rays are used which have passed an aluminium filter 2 mm. thick, and it may represent only one-eighth when a zinc filter 0·5 mm. thick is used. With Sabouraud pastilles the difference would be a little greater still, because platinum has a higher specific gravity than silver. But it would be going too far to conclude from this that chromo radiometers have become useless. *When used with the same quality of rays, the same intensity will produce the same degree of discoloration*: how many "Teinte B's" or x of the Kienböck scale are approximately required to produce an erythema dose with various filters, will be found in tables Nos. 18 and 19, on page 133.

The Kienböck quantimeter strips are also very useful for testing and comparing the efficiency of various tubes and apparatus required for the treatment of deep-seated organs, and for determining the percentage of the surface dose which will reach various depths, as we shall see later on.

The Ionto Quantimeter.—X rays "ionize" the air through which they pass and thereby make it a conductor of electricity. If an electroscope is charged, the gold leaves or segments repel each other so long as they are charged with electricity of the *same* polarity. When the air surrounding the electroscope is traversed by X rays, it becomes conducting on account of ionization and so the charge on the electroscope leaks away. This becomes apparent by the collapse of the gold leaves.

This fact was used by Dr. Szillard, of Paris, to design an instrument to measure the intensity of the X rays. In a small case lined with lead to protect it from the X rays are two aluminium vanes. One is fixed, and the other is suspended, parallel to the first but insulated from it, on an axis so that it can swing to and fro. A pointer moving over a scale is attached to it. One of the aluminium vanes is connected to a flexible copper cable about two yards long, which is heavily insulated with india-rubber. The other vane is connected with a flexible metal tube enclosing this cable and connected to earth. At the end of this cable is the "ionizing chamber," consisting of a short cylinder of aluminium, which is connected with the metal tube. Inside it is a wire, insulated from the aluminium with a ring of amber, but connected with the flexible copper cable. The aluminium cylinder and the wire are thus the terminals of the electroscope.

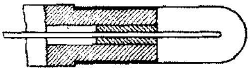


Fig. 27.

When the two aluminium vanes are charged with electricity of the *same* polarity from a small static machine, they repel one another, and the pointer moves to the opposite end of the scale. It remains in this position until a discharge begins, which will be the case when the air in the ionizing chamber is struck by X rays. It then becomes a conductor and the electricity can begin to discharge through it, the pointer falling back gradually to its original position. The time required for this varies with the intensity of the rays reaching the ionization chamber.

The principle of the instrument is correct, and it gives much more accurate results than the two types of quantimeters described above. As a consequence, however, it is also much more delicate and requires careful attention and control, so that defects may not arise which would cause serious errors in the readings. It was soon found that the lead lining of the instrument gave rise to secondary rays, and that the size of the ionization chamber had a considerable bearing on the readings. To obviate the first trouble, a wooden case lined with lead on the outside was placed over the electrometer and earthed. As regards the size of the ionization chamber, it became evident that for hard rays the small thimble-like aluminium tube had dimensions which were too small. The size of the chamber was therefore considerably increased. It can be exposed on the body or, preferably, in a phantom of water, as will be described later on. The electrometer is charged by means of a small static machine attached to the instrument.

Quantimeters of this type, based on ionization effects, have now superseded the older chemical quantimeters. They are indispensable to physical research laboratories, to the physical departments of large hospitals and to medical men who carry out deep therapy in private practice, but the handling of them must be understood and the principles upon which they are based must be carefully studied. The details of how they are to be used so that reliable readings may be obtained are fully set out in instructions for use which accompany them.

Radium Balance Method.—Quite recently it has been established by Prof. Russ and Dr. Martius that there is a variation in the ionizing property and the biological effect of X rays of different wave lengths. Thus, if we cause the same amounts of X-ray energy to be absorbed from a long wave (soft) and a short wave (hard) radiation, we find that the soft rays produce both more ionization and more biological effect. In order that ionization methods may be useful for intensity measurements when rays of varying wave length are used and compared, it is essential that a constant degree of ionization shall be available for comparison. This can be obtained from radium, and Prof. Russ has described a balance method whereby the X-ray ionization can always be compared with that produced by a known quantity of radium.

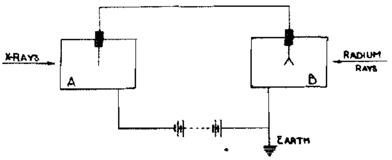


Fig. 28.

Two ionization chambers A and B are so placed that A is exposed to X rays and B to radium rays. The electroscope in B is connected by a conductor to a metal stem projecting into A. Both the stem and the electroscope are very carefully insulated from their surroundings. The outer walls of the two ionization chambers are connected to a source of electric supply of 200 volts continuous current, and in addition the wall of the chamber B is earthed.

If now A is exposed to X rays while B is unexposed, the air in A becomes ionized and the stem receives a charge from the 200 volts supply. The leaves in B therefore separate. When the radium is brought up to B, the air in this chamber becomes ionized and some of the charge on the electroscope can leak away. The leaves therefore collapse somewhat, though not altogether. The final position which they assume is a measure of the relationship between the ionization due to the X rays in A, and that due to the radium rays in B.

Dosage for Therapeutic Exposures.—None of all the instruments mentioned is quite sufficient alone for the dosage of therapeutic exposures.

When the quality of the X rays is known, the milliampère meter enables us to obtain correctly exposed negatives of the various parts of the body. The exposures required for therapy, however, last fifty to several hundred times as long, and the milliampère meter gives information only about the intensity of the X rays which are produced in the tube. It does not take account of the anticathode skin distance, the filter, the absorption by the body, and the scattered radiation, which all affect the intensity of the rays before these finally reach that part of the body which is to be treated. A small error in the estimation of the effect of these factors and of the quality of the rays might have serious results in exposures of long duration. In this respect the chromo radiometer and the Ionto quantimeters are better, for they measure the intensity which actually reaches the spot where they are situated after it has been influenced by distance and filter. And if they are introduced into cavities in the body, the effects of absorption and scattering are allowed for as well. But the Ionto quantimeter is rather complicated for everyday use in the wards of a hospital, and the indications of the Kienböck quantimeter vary with the quality of the rays and are not available till the strips have been developed. Moreover, it is inconvenient for patients to have either of these instruments inserted in cavities, such as the vagina or the rectum, for an hour or even longer.

To "measure" anything we must have a well-defined unit with which quantities which we are measuring can be compared, like the freezing or boiling of water, etc. The generally recognized unit for the biological effects produced by the X rays is the

Erythema.—The first evidence of this is a slight redness of the skin appearing soon after the exposure. This colour changes within two to three weeks to brown, and leaves a permanent brown bronzing of the skin.

This unit is fairly accurate in so far that the latitude in the dose required to produce just this effect is not great. When the dose is too small no permanent discoloration will follow; when it is a little too great blisters will appear and the skin peel off, or, if the duration of the exposure has been exceeded to a larger extent, a serious burn with ulcerations will follow. Numerous experiments and actual exposures have proved that when the skin of the *same part of the body* is exposed the difference in the reaction of

grown-up patients does not exceed 10 per cent. The skin of the neck and shoulder is the most sensitive. Next follows the skin of the abdomen, then that of the upper legs and the back, whilst the skin of the face is the least sensitive. *Light-haired patients are about 10 per cent more sensitive than* dark-haired ones, and only patients suffering from tuberculosis, diabetes, exophthalmic goitre, nephritis or syphilis make an exception, and are more sensitive. The part of a patient's skin which has already been exposed to the X rays also remains more sensitive for a few weeks or even months than a skin which has not yet been exposed.

The erythema dose as a unit is, however, rather inconvenient, because it takes such a long time till the results show whether the exposure was just right to produce an erythema, or whether it was too long or too short. It is also insufficient because it shows only the intensity of the rays which prevailed *on* the skin, but does not indicate the intensity of the rays which penetrated to objects 6 or 10 cm. *below* the skin. It is therefore necessary to employ electrical or chemical quantimeters which enable us to determine the dose during the exposure on the skin, or at various depths below it.

When the efficiency of a tube and apparatus has been carefully tested with the help of an Ionto quantimeter or a Kienböck quantimeter, the duration of an exposure can be determined with sufficient accuracy by the length of time only.

Dosage by Length of Time.—*As long as no change takes place* in the voltage supplied by the main, the frequency of the interruptions, the distance between the anticathode and skin, the filter, the aperture of the diaphragm, the number of M.A. used, and the penetrating power of the tube, *the intensity reaching the object will remain the same*, and the effect will vary with *the length of time during which the rays are allowed to act.* There is no difficulty in using the same distance, filter, diaphragm and number of M.A., but attention and experience are required to maintain the penetrating power of a tube perfectly constant during exposures of long duration. The changes which may occur, and their causes, have been explained on pages 26–29. They can be avoided, or they may be kept very small by using tubes with an arrangement to prevent excessive heat, such as tubes whose anticathode is kept at the constant temperature of boiling water, and by using a moderate current which suits the individual tube. With tubes which are made so that they become harder soon, it is necessary to use an automatic regeneration described on page 29, by means of which the current can be kept perfectly steady.

In addition to the M.A. meter it is, however, necessary to watch the *voltmeter in the primary circuit* carefully too, because the E.M.F. supplied by some central stations varies somewhat; this is the weak point, and may lead to failures when exposures are made by the length of time.

If a tube was tested while the normal E.M.F. of say 220 volts was being supplied, and the M.A. meter indicated 2·2 M.A., and the exposure is then made

.t a time while the E.M.F. has dropped to 200 volts, the rays emitted by the tube vill be softer for the following reason: With the lower E.M.F. in the primary ircuit, the E.M.F. induced in the secondary circuit will drop 10 per cent too, he rays emitted will become somewhat softer, the filter will absorb a greater juantity of them, and *the motor of the interrupter will work at a lower frequency.* 'he result of all this is that when the E.M.F. of the main drops 10 per cent only, he duration of the exposure may have to be increased as much as 40 per cent o avoid an under exposure.

The automatic regeneration of the tube will be no help in such a case; on the ontrary, it may exaggerate the condition, because if the number of M.A. alls on account of the lower E.M.F. and frequency, it will begin to work and nake the tube softer, till the set number of M.A. has been reached again. To uard against this, the voltmeter of the primary circuit has to be watched arefully.

It is not difficult to maintain the frequency of the interrupter at a constant gure, if an additional voltmeter is connected with the terminals of the motor f the interrupter, and a variable resistance is available. If the normal E.M.F. upplied by the main is, for instance, 220 volts, sufficient resistance is inserted so hat the motor is operated by 180 volts only. If the voltage of the main should rop, the resistance in the motor circuit has to be reduced until the voltmeter f the motor circuit again indicates 180. The frequency of the interruptions an thus be kept constant even if the E.M.F. of the main should vary, and the lifferences in the intensity due to a 10 per cent drop will not be nearly as great s mentioned above. A good speed indicator which allows the number of revoluions at which the motor is revolving to be ascertained at a glance is still better han a voltmeter.

The changes occurring in the E.M.F. of the main are as a rule not very requent or great, and one nurse can usually attend to two sets of apparatus t the same time. If there should be an unexpected and unusually great rop in the primary voltage, it may be best to interrupt the exposure till ormal conditions prevail again. In circuits, however, in which fluctuations f 10 per cent, or even more, are frequent, it may be necessary to insert a uitable variable rheostat, which reduces the E.M.F. of the main from say 40 to about 200 volts. If the normal E.M.F. should drop, resistance is cut ut till the voltmeter indicates 200 again. There are also relays, which vary uch a rheostat automatically, they work quite satisfactorily, but are rather xpensive, and a detailed explanation of them here would lead too far.

Testing the Efficiency of various Tubes and Apparatus.—With an quivalent spark of about 37 cm., a distance of 23 cm. between anticathode nd skin, and a zinc filter 0·5 mm. thick, with some apparatus and tubes the rythema may be produced in 18 minutes already, with others double this ime may be necessary. This difference is due to the fact that the percentage f hard rays emitted varies somewhat with the individual apparatus and ubes used for reasons which have been explained. But even tubes from he same manufacturer and of the same construction vary slightly. Some llow a higher voltage and number of M.A. to be used than others. It is herefore necessary to test the exact wave length with a spectrometer, or lse to find empirically the time in which the erythema dose is reached with . given apparatus and tube. There are various ways of doing this, and a uggestion how it can be done will be found on pages 93 and 94.

When the length of exposure required to produce an erythema with a given tube has been found out, this tube should not be used any more for other exposures, but should be kept as a standard, so that other tubes can be compared with it. This can be done in various ways. The spectrometer or Ionto quantimeter is best, but if neither of these is available, the Kienböck quantimeter may very well be used for the purpose; even though the value of the tints varies with the quality of the rays which are being used, the degree of discoloration is in proportion to the intensity which reached the strip as long as the quality of the rays remains the same.

Six Kienböck strips can be placed between two cubes of beeswax, not less than 5 cm. thick each way, to expose them to the influence of the scattered rays too, and so arranged that the distance between the anticathode and strips is 50 cm. Two are exposed with this standard tube, with a current of 2·2 M.A. for 100 seconds. The other strips are exposed for 80, 90, 110 and 120 seconds. All the strips are developed simultaneously, in a developer of standard strength and temperature, for 60 seconds (a longer time may be used if desired, but the *same* length of time must be used in all cases); they are rinsed in water, fixed and thoroughly washed, to be kept as *references*. To test and compare the efficiency of other tubes or apparatus, strips are exposed under exactly similar conditions as to current, filter, distance, etc., for 100 seconds. They have to be developed in the same way, and the depth of the tint which they assume indicates by comparison whether the *intensity of the rays obtained with the tube* to be tested is the same as, or greater or smaller than, that obtained with the standard tube.

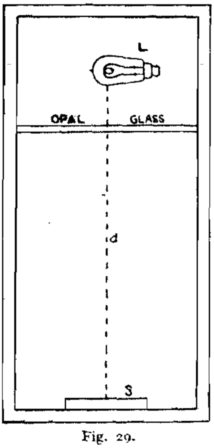


Fig. 29.

If the tint obtained with the new tube with 100 seconds exposure should be similar to the tint obtained with the standard tube in 110 seconds, it would mean that the intensity of the rays was 10 per cent greater. To obtain an erythema, the exposure with the new tube would have to be 10 per cent shorter than that which is necessary with the standard tube.

For some purposes it is convenient to have a scale of about 20 different tints of these strips, *increasing in a known ratio*. Such a scale can be obtained in the following manner: a light-tight box, about 50 cm. high, bears a partition 10 to 15 cm. from the top. In the centre of this partition, an opening with a diameter of about 10 cm. is cut, and this opening is covered with a piece of milk glass. In the upper part, an incandescent lamp is placed (see Fig. 29). On the bottom of the lower part, quantimeter strips are placed. One strip is exposed for 60, the next for 65, the third for 70, etc., seconds, the twentieth for 160 seconds. They have to be developed *simultaneously* for the same length of time. The upper end of the strips can be fastened for this purpose with drawing pins to a piece of

cardboard or thin wood. A series of strips with gradually increasing densities can thus be obtained, and when strips exposed with different tubes or apparatus are compared with such a scale, it is easy to ascertain whether the difference in the various intensities has been 5 or 10 or 20 per cent, etc.

With *new* tubes, the current should be switched on for 5 to 10 minutes before trial exposures are begun, because the current is frequently somewhat unsteady during the first few minutes with such tubes, or with tubes which have not been used for a considerable time.

It is not only necessary to know the time in which an erythema can be produced, but also the

Difference between the dose on the surface, and that obtained at various distances **below the surface,** or in other words, **the percentage of the surface dose which will penetrate to various depths.**

It is of great importance that this percentage should be as large as possible, for the greater it is, the smaller will be the total dose of X rays which has to be administered to the body, and the smaller also the injurious effects to the skin, the blood, etc., before the cells of the ovaries or malignant cells receive the lethal dose intended for them.

This percentage depends on :—

1. **The quality of the radiation.**—The greater the penetrating power of the rays, the smaller will be the amount absorbed by the tissues overlying the organ which has to be treated and the greater will be the intensity reaching it. The quality is determined by the E.M.F. on the terminals of the tube and by the filter. It can be measured with a spectrometer or an absorption meter.

2. ***The distance between anticathode and skin.***—*The greater this is, the* smaller will be the difference between the dose reaching the surface and the organs lying 6 to 10 cm. below the surface (see table, No. 8, on page 128). If this is, for instance, 50 cm., and if the uterus is 10 cm. below the surface, the difference in the distance will cause a loss of intensity of only 30·5 per cent of the intensity of the rays at the surface ; but if the distance between the anticathode and skin is only 25 cm., the difference in the intensity of the dose between the 25th and the 35th cm. will be much greater, and the loss due to this cause will amount to 49 per cent of the surface intensity. It would, therefore, be an advantage to use large distances, but the larger they are, the smaller will be the intensity of the X rays reaching the object, and the longer will have to be the exposures. (See tables, Nos. 5 and 6, on page 127.) A compromise is therefore necessary, and the distances which have been found best for various purposes are mentioned later on.

3. **The area of the window on the skin,** i.e., the area of the opening of the diaphragm. When the cone of rays entering the body has a large diameter the quantity of scattered rays is large and the object to be treated is exposed to a greater quantity of them than when the cone is smaller (see page 9 and table, No. 21, page 135).

To obtain a higher percentage depth dose it is not sufficient to increase the focus skin distance only, the area of the window used has to be increased too. Unless this is done, the volume reached by the X rays would become smaller, the more the focus skin distance is increased, because the cone of the rays cannot diverge any more as widely as it can with a shorter focus skin distance. This becomes apparent from the illustration. The truncated cone *a, b, c, d*, encloses a greater volume than the cone *a, b, e, f*. With the reduced volume, the quantity of scattered rays becomes smaller and this diminution would neutralize any gain, which an increase in the focus skin distance would otherwise produce in the percentage of the depth dose.

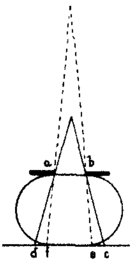


Fig. 30.

4. **The distance of the object to be treated below the skin.**—*The greater this is, the more is the intensity* of the beam reduced by absorption.

The factors 2, 3 and 4 are linear measurements of which 2 and 3 are easily made, and 4 depends on a knowledge of the exact position of the object. The first factor is determined by the spectrometer.

Tables exist from which the ratio of the dose at a depth to the surface dose can be ascertained, as a percentage, when the four factors mentioned above are known (see tables, Nos. 20–24, pages 134–138).

On the other hand, this ratio can be determined experimentally with the help of a

Phantom.—This must consist of a material which absorbs X rays to the same extent as do the tissues of the human body. As water absorbs only 5 per cent less than a mixture of muscles and fat, it fulfills this condition well, and is frequently used for this purpose. A phantom consisting of a mixture of 20 per cent beeswax and 80 per cent paraffin is more convenient, but a little more expensive than one of water. Ten sheets of this mixture, each 2 cm. thick and 20 by 20 cm. square, and protected at the sides by suitable frames of oak wood, can be used instead of a tank of water for the arrangement of the chromo radiometer strips or pastilles or other test objects, at the various depths.

Either the Ionto quantimeter or the Kienböck strips can be employed. If the former is available, then the rate of discharge of the electroscope is observed when the ionization chamber is exposed to the direct influence of the filtered X rays at a distance of say 50 cm. from the anticathode, and when it is at say 60 cm. from the anticathode, and a tank of water 10 cm. thick is interposed between the filter and the chamber. Two water tanks should be employed, and they should be made of ebonite or glass, but there *must be no metal, as this would generate secondary rays and influence the* result.

In the first case, the ionization chamber would be in front of both of them, being, as it were, on the skin. In the second case, it would be between them, that is to say, 10 cm. below the skin. Thus, the scattered radiation due to the body which is approximately 20 cm. thick would be

reproduced. The intensity of the rays is inversely proportional to the time of discharge of the electroscope and so the ratio of these two observed times gives us the ratio of the depth dose to the surface dose.

If the Kienböck strips only are available, we use a tank of water constructed as before, but 20 cm. deep and about the same in the other two dimensions. *In this three Kienböck strips, enclosed in suitable envelopes to protect them* from the water, can be arranged so that they are 6, 8 and 10 cm. below the surface. On the surafce of the water, about 6 strips are arranged; they may be placed on a sheet of wax, about 5 mm. thick, as wax is very transparent to the rays and floats on water. Care must be taken that the strips are distributed in such a way that they do not intercept and weaken the rays which are to reach the strips lower down, and that all the strips are as near the cone of the central rays as possible.

On the rim of the box is placed a sheet of celluloid, or wood, 3 to 5 mm. thick, to absorb the secondary rays which emanate from the metal used for the filter and diaphragm. A sheet of lead, with an opening as wide as the aperture of the diaphragm to be used, and the filter are placed above the wood, and the X-ray tube is adjusted so that the distance between the anticathode and the surface of the water is as great as the distance we intend to use between anticathode and skin, and that the anticathode is in such a position that all the strips below are near the central rays.

Experiment No. 1.—*The exposure has to be made with the same frequency* of the interrupter, the same E.M.F. and strength of current in the primary coil, and the same number of M.A. in the tube, as we intend to use later on for the exposures on the patients.

As it is known from the experiences already gained by others, that with good tubes with an equivalent spark of about 37 cm., a distance of 23 cm. between anticathode and skin, a filter of zinc 0·5 mm. thick, a current of 2·2 M.A. through the tube, a gas interrupter with a frequency of about 2400 interruptions per minute, and a good electrical apparatus, the erythema dose can be produced in from 20 to 36 minutes, it is best to begin with an exposure of 20 minutes' duration.

When it has lasted 2 minutes it is stopped and one of the strips on the surface is withdrawn. The second is withdrawn after it has received a total exposure of 3 minutes, the third after 4, the fourth after 6, the fifth after 8, the sixth after 10 minutes. The exposure is then continued till a total of 20 minutes has been reached; after this the strips exposed at the various depths below the water are withdrawn too. The latter can be marked with *the figures 6, 8 and 10 cm., to indicate the respective depths in cm. at which* they were exposed; those on the surface may be marked with the figures 10, 15, 20, 30, 40 and 50 per cent, to indicate the percentage of the total exposure which they received.

They are then developed simultaneously, fixed and washed, and when they are dry the tints are compared. If the tint of the strip which was exposed at 8 cm. depth is similar to the tint of the strip which was withdrawn

after 4 minutes' exposure, this would show that the dose prevailing at a depth of 8 cm. was 20 per cent of the dose which reached the surface. If it shows a tint similar to the strip which was withdrawn after 3 minutes, the dose prevailing at the depth of 8 cm. would have been only 15 per cent of the surface dose.

The strips are then pasted in a case book, or on a card as used for card indexes ; ten strips and the necessary text require a card not less than about 5 × 8 inches. The text should run about as follows :—

Tube No. 1.		Oct. 18, 1924.
Frequency of the interrupter	..	2400 interruptions per minute.
Primary current ..	..	220 volts, 3·5 amps.
Secondary current ..	..	2·2 M.A.
Equivalent spark ..	..	35 cm.
Filter	..	0·5 mm. zinc.
Aperture of diaphragm	..	6 × 8 cm.
Distance anticathode skin	..	23 cm.
Exposure	..	20 minutes.
Strip exposed at 6 cm. depth shows		%, at 8 cm. %, at 10 cm. % of the surface dose.

Experiment No. 2.—To gain more experience, and to get the figures more accurate, it is well to repeat the experiment, and this time to withdraw the strips on the surface after 3, 5, 7, 9 and 12, or 15 minutes, thus obtaining more, and intermediate tints, as control. Otherwise we proceed as explained in Experiment No. 1.

With *new* tubes it is wise to make another trial exposure after they have been used for about 6 hours. Good tubes can then be used for 100 to 150 hours without risk of a change taking place in them, but they should be tested after that time once more. Some 500 hours' work can be got out of good gas or Coolidge tubes. Each tube should receive a number and a card on which the cases for which it was used are entered.

THE PRACTICAL APPLICATION OF X RAYS FOR DIAGNOSTIC PURPOSES.

Besides the X-ray tubes and the apparatus supplying currents of suitable voltage, a stand to hold the tube, a couch, a fluorescent screen, and various other accessories are necessary.

As individual requirements vary widely, it is not my intention to describe here in detail a large number of different constructions of tube stands, couches, etc., as these things can be found in illustrated price lists. I will give only an explanation of the objects for which some of these

accessories have been constructed, as it may help the readers to decide whether they will be necessary for their special requirements.

The X-ray Room should not be too small. There must not only be space for the apparatus, but also room for the patients to undress, a wardrobe stand, or hooks, and some chairs, as a relative may accompany a patient, and the operator must be able to move about even while the room is dark.

In a large majority of cases it is an advantage if the patients can be examined first on a fluorescent screen. Partly for this purpose, and partly for examining negatives for fine details, it should be possible to make the room completely dark. It is an advantage to have an electric lamp either in a glass bulb of dark-red colour, or else two lamps of small candle power connected "in series," so that each receives only half the voltage for which it is intended. They will then give only a dull-red glow. The last preparations of placing the patient in correct position, fetching screen or plate, etc., can be made while the room is in semi-darkness already. The pupils of the eyes then have sufficient time to dilate, and we have not to wait over five minutes for this purpose, after the room has been made completely dark, before the examination on the screen can begin.

The wires leading to the tube should not be in the way of anybody moving about in the darkness. It might cause most unpleasant shocks, and even the destruction of a tube! They should be fully 50 cm. above the head of a grown-up man. They can be supported on porcelain insulators fixed securely on the ceiling. It is wise to use two insulators for each wire, in case one should crack or become detached. The wires should lead down perpendicularly to the tube. If the position of the latter has to be varied, or if different tube stands have to be used, wires connected with the terminals of the coil can be stretched beneath the ceiling like telegraph wires, and small wheels with deep grooves, to which the cables leading to the tube are fixed, run along these wires.

There should be a distance of at least 5 feet between the electric apparatus and the tube, otherwise the cathode rays may be deflected from their path by the magnetism of the iron core, and the focus would become unsteady and the outlines of the organs unsharp. The wires must be connected so that the current passes in the correct direction through the tube. They must be fastened securely to the eyelets of the tube, so that they cannot possibly fall off. They must not come near the bulb of the tube, otherwise sparks might pierce the thin glass, and they must not cross one another, otherwise the discharge might take place through the air between these wires.

It is necessary that the X-ray room can be well ventilated. The spark and brush discharges generate ozone and gases of nitric acid, which have an irritating influence on the respiratory organs and cause frequent headaches to the operators. A sufficient

Protection from X rays for operator and patient requires most careful consideration. In spite of the numerous victims which have been claimed by X rays in the first years, before their toxic action was known, and

before protecting boxes, filters, etc., were used, some people are inclined to forget that even weak doses, when often repeated, may produce serious injuries.

The necessary degree of protection, however, varies widely. In the majority of installations, where the apparatus is used, say ten to twenty times a month for exposures not exceeding about ten minutes each, including the examination on the screen, the protection offered by a box lined with impregnated rubber, such as are now used universally, and in which either the whole tube, or at any rate the luminous half of it is covered, is sufficient. Only a small aperture is left opposite the anticathode, and various flat or cylindrical diaphragms and filters can be attached to these boxes. It is necessary that the diaphragms and filters, or other metal parts, do not come too close to the bulb of the tube, otherwise sparks might discharge between tube and diaphragm, and between the latter and the patient. With gas tubes, practically no X rays are emitted from the part of the tube *behind* the anticathode. It is therefore sufficient if the protecting box covers the luminous half of the tube. Coolidge tubes have to be enclosed all round, because with them a fair quantity of rays is emitted even from the part behind the anticathode.

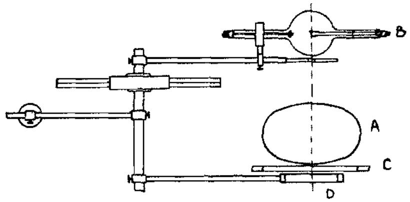
In diagnostic work, the protection of the operators is more important than that of the patients, because they may have to make several exposures in the course of a week. The patients are seldom exposed for more than ten minutes, even if several exposures have to be made, and comparatively large distances are used in most cases between anticathode and skin. But if the abdominal region of male patients has to be exposed, it is necessary to protect the testicles by a piece of lead rubber, and a filter of aluminium about 1 mm. thick should be used. It must be remembered that with unfiltered rays, an erythema may be produced in considerably less than ten minutes, with a distance of 25 cm. between anticathode and skin. As *one-third* of the erythema dose is sufficient already to produce sterilization of the ovaries, it is very likely that many men have been sterilized unconsciously, if exposures near the abdomen were made without a filter and special protection of the testicles. An aluminium filter 1 mm. thick stops only the softest rays, which would not pass through the abdomen; it does not therefore prolong the exposure materially, but it does reduce the danger considerably. A filter of this kind is also to be recommended for prolonged examinations of other parts of the body on the fluorescent screen.

The matter becomes quite different for installations where the X rays are to be used daily for a large number of exposures. In such cases the operators watching and controlling the instruments have to stand behind screens lined with lead 2 mm. thick, and provided with windows of lead glass about 7 mm. thick. These screens should be not less than 240 cm. high and about as wide, so that even "scattered" rays of any strength become sufficiently weakened by the long distances they have to traverse before they can reach the operators.

In the X-ray departments of large hospitals, or where X rays of the

greatest penetrating power are to be used, for the therapeutic exposures of deep-seated organs, the X-ray proof partition between operator and patient should reach from floor to ceiling and the lead must be at least 3 mm. thick. Special lead glass, containing 10 per cent of lead, but polished on both sides and very transparent, and not less than 20 mm. thick, should be used for the windows of these partitions. When Coolidge tubes are used, the floor, walls, and ceiling have to be protected with sheet lead, as otherwise people living in the adjoining rooms may be injured, and the efficiency of the protection should be tested from time to time, by exposing Kienböck strips for a few days, at various places behind the partition and in the adjoining rooms.

The fluorescent screens should be protected with plates of lead glass, and with metal shields covering the hands of the operator. The hands and arms of nurses holding a child in position require good protection too. Impregnated rubber gloves may be used, but as they have to be fairly thick they are not convenient. In many cases flat pieces of impregnated rubber, about 40 cm. long and 15 wide, can be fastened with straps attached to them, above the lower arms and hands so that arms and hands are well protected, and the hands are nevertheless left free to move unhindered. Lead-glass spectacles may be desirable in some cases too. It is well to remember that these lead glass plates, shields, gloves, etc., offer no absolute protection, but they weaken the intensity of the rays so much that it would require a total exposure exceeding a hundred hours to produce even a faint darkening of a photographic plate. It is wise occasionally to make a trial exposure, because some protecting materials may become defective in course of time.



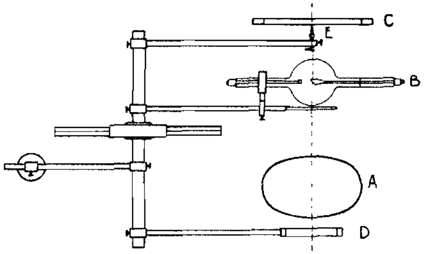
A = Patient.
B = Tube.
C = Plate holder or drawing board on which tracings can be made.
D = Screen.

Fig. 31.

The Tube Stands.—The tubes must be suspended in such a manner that they may be easily shifted in any direction. In some cases, strong parallel brackets which can be raised or lowered about 70 cm. are sufficient, but usually wooden or metal stands are preferable. The former have the advantage that little metal need be used in them, and that they are comparatively cheap. They must, however, be strong enough to carry the fairly heavy protecting box. The vertical arm carrying it can be raised and lowered and moved

forwards and backwards by a crank, with rack and pinion; a counter-weight to balance the weight of the protecting box is a great convenience.

For many cases, tube stands of metal are preferable. They are more rigid, and it is easier to use them for compression, which is necessary for many exposures and for making stereoscopic pictures. There is less risk that the direction of a cylinder diaphragm, etc., may be altered by an involuntary movement of the patient, and they can carry heavier protecting boxes, which



A = Patient. C = Drawing board for tracings.
B = Tube. D = Screen.
E = Pneumatic pencil.

Fig. 32.

are balanced by a heavy counter-weight moving up and down inside the central steel column.

In some cases the stands are so arranged that they can also carry a fluorescent screen, which moves simultaneously with the tube, so that its centre is always opposite the anticathode; a plate holder containing the photographic plate may be slipped in place of the screen to make an exposure. Tracings of the outlines of the heart may be made, and for this latter purpose

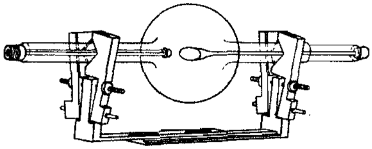


Fig. 33.

it is necessary that tube and screen are so carefully balanced, and move in roller bearings, that they easily respond to the touch of a finger. A pencil passing through the centre of the screen, so that it is in the axis of the central ray, is moved along the outlines of the shadow of the heart, and dots or lines can be drawn on a sheet of paper, which is fixed between the fluorescent screen and the patient, or behind the patient's back, on a thin drawing board.

With all tube stands, it is necessary that the tubes can easily be exchanged and fastened in such a position that the centre of the anticathode is above the centre of the aperture left in the protecting box. For this purpose it is a great convenience and saving of time to have a plain wooden holder for each tube. These holders grip the neck of the tube, and are provided with a rail, which slides into a groove arranged at the bottom of the protecting box. *New tubes are fixed and centred in these holders, and then remain* in them for all their lifetime. The tubes can thus be slipped in and out of the protecting boxes quite easily, and are placed in correct position without loss of time.

Diaphragms.—*The secondary and scattered rays tend to reduce the* sharpness of the outlines and thus cause many small objects and fine details to be lost. As their quantity increases with the diameter of the cone of rays, it is necessary to reduce this diameter as far as possible, and this object can be achieved if diaphragms of various apertures—or better an adjustable rectangular diaphragm—are attached to the box enclosing the tubes. The aperture to be given varies with the distance between anticathode and plate, and with the size of the plate to be covered. It is easy to find the area covered by placing a fluorescent screen on the spot to be occupied later by the photographic plate. The area can also be found by making a sketch; when the distance between anticathode and diaphragm is 15 cm., and the aperture of the diaphragm 10 cm., the diameter of the illuminated area will be 20, 27, 34, 40 cm., when the distance between anticathode and plate is 30, 40, 50, 60 cm.

The advantage of a cylinder diaphragm and of a Potter Bucky diaphragm to eliminate the scattered radiation which is produced when the train of X rays passes through the air and the patient's body has already been described (see pages 34 and 35).

A **Couch** is necessary on which patients can be placed in the horizontal position. It should be 6 ft. long, 2 to 2½ ft. wide, and about 2¾ ft. high. A strong wooden frame, on four heavy legs, with a top of three-ply wood about $\frac{3}{16}$ in. thick, is generally used. The tubes can then be used above or below this couch. The latter is especially convenient for examination on the fluorescent screen. With more elaborate couches, the box containing the tube is not suspended on a stand, but runs on rails fixed below the couch. It is convenient if one-third of the length of the top of the couch can be raised, so that the head and back may rest against it, and holders for the legs, as on gynæcological chairs, are frequently attached to the other end.

Couches can also be so arranged that the frame, which has to consist of metal for this purpose, swings in two pivots, so that it can easily be brought in the vertical or horizontal position, without disturbing the patient, so that the heart, or the position of the stomach, etc., may be examined while the patient is lying, standing, or sitting.

Selecting Tubes with Suitable Penetrating Power.—It has been mentioned already, that the quality of the negative depends to a large extent on whether

the X rays used have a suitable penetrating power for the object to be examined. In order to reduce the duration of the exposures, the intensity and penetrating power are frequently increased as far as the tube and apparatus will permit, but this is bound to increase both the radius of action of the scattered rays, which blurr the sharp outlines, and also the transparency of the object which is due to a diminished degree of absorption. Small differences in specific gravity no longer cast a shadow, and thin foggy negatives are frequently the result.*

For a large number of cases, for fractures, dislocations, large foreign bodies like bullets, etc., considerable latitude is permissible in the penetrating power used, but for finding diseases of the bones, arteriosclerosis, small stones or foreign bodies, phleboliths, etc., it is not possible to obtain a *reliable* diagnosis from a negative unless the penetrating power used is fairly correct.

It will be best if the quality of the rays which can be obtained from each individual tube is ascertained with the help of a spectrometer, while currents of 2·5, 5, and 10 M.A. are used. The result can be written on a piece of stamp paper to be attached to the neck of the tube, or better on a card kept for each individual tube.

I should like to draw attention to a mistake which is made rather frequently. The testing of the penetrating power of the rays obtained from a particular tube may take longer than most actual exposures, especially if currents of 10 to 20 M.A. are used. To avoid the risk of the tube becoming softer, while the penetrating power is being found with a strong current, it is usual to employ a weak current of only a few M.A. for this purpose, and the fact is overlooked that the penetrating power may be twice as great when much stronger currents are used. Table No. 9, page 129, shows how the penetrating power increases when the number of M.A. is raised by increasing the strength of the primary current. The rate of increase varies considerably with soft, medium, and hard tubes, and to a smaller extent even with different tubes of similar penetrating power. This is the reason why it is best to test each individual tube with *various* strengths of current, and the exposure should then be made with the number of M.A. with which the penetrating power best suited for the particular object is obtained from the particular tube.

The exact wave length or quality of the rays which it is best to use for various thicknesses and parts of the body have been found out empirically (see the tables on page 129), and from the calibration we see at once with what number of M.A. a tube should be used to give this quality of rays. Of course, it remains constant only as long as no change takes place in the

* The negatives obtained in the early days after the discovery of X rays have shown nore details and contrasts than the large majority of the present-day negatives do. This s due to the smaller percentage of hard rays supplied by the apparatus which was then .vailable. The 10 to 18-in. spark coils, connected with 6 accumulator cells, gave only hin blue sparks, and the maximum spark length which could be obtained was scarcely per cent longer than the nominal one, whereas many of the present-day coils, working ith currents of 200 volts from the main, can give sparks 30 per cent longer than the istance between the spark pillars, and the percentage of hard rays emitted is much

vacuum of the tube, but modern tubes with good cooling arrangement of the anticathode are remarkably constant. To detect any alteration in this respect, the indications of the volt and ampèremeter in the primary circuit, with which the particular number of M.A. has been reached when the penetrating power was tested, should be noted too.

Examination on the Fluorescent Screen.—Most patients should be examined first on the fluorescent screen. In a few cases this alone will give sufficient information, so that no exposure will be required on a photographic plate. In the majority of cases, subsequent exposures on a plate will be desirable, partly to obtain a permanent record, and partly because a good negative shows more details than the eye can discover on a screen. But even if it is certain that a negative has to be made, a previous examination on the screen is desirable, because the area which should appear on the negative, and the position of the patient, which will show the injuries best, can thus be found out. As the examination on the screen may last a considerable time, it is not advisable to use currents as strong as those employed for making exposures on a photographic plate, because the tubes would not stand these strong currents well for several minutes. And moreover it is not necessary, because, provided that the pupils of the eyes are well dilated, we can discover much on the screen even with a current of only a few M.A. The examination should not begin till some time after the ordinary day or electric light has been excluded. The room should be perfectly dark; even the green light of the tube should be suppressed by enclosing the tube in a box protecting it all round, or, if only the luminous half of the tube is covered with a protecting box, by covering the back part of the tube with a black silk cloth of suitable size.

Frequently, the examination is begun before the pupils have dilated sufficiently, and if the observer cannot then detect all the details he wishes to see, the strength of the primary current is increased in the hope of improving matters. This is a mistake. Though the intensity of the rays and their penetrating power rises rapidly, the luminosity of the screen and the amount of details do not increase at the same rate, because the quantity of rays which traverse the patient and the screen without being absorbed increases rapidly, and thin small objects no longer cast a shadow. As the patients are frequently brought quite close to the tube, the intense rays may cause injuries. Whenever it is likely that the examination on the screen may last more than one minute, it is strongly recommended to use an aluminium filter, 1 mm. thick, to exclude the softest rays, which would otherwise be absorbed by the skin without reaching the screen, and which may cause an erythema within a very few minutes.

An adjustable diaphragm should be used with all examinations on the screen to reduce the amount of scattered rays.

For many years, barium platino-cyanide was used exclusively for these screens. It gives a good light, but these expensive chemicals deteriorate gradually and become useless after having been exposed to X rays for a certain length of time. Other chemicals are therefore preferred now, which are

cheaper, and do not lose the property of becoming fluorescent under the influence of the X rays. Some of them have the disadvantage that a phosphorescence continues for a few moments after the rays have ceased. This has the effect that the outlines appear slightly blurred when the screens are moved quickly over the patient's body, but as a rule this becomes apparent only when fairly strong currents are being used.

With the **Photographic Plates**, less progress has been made. The difference between the special X-ray plates and plates for landscape and portrait photography consists chiefly in the thickness of the coating of bromide of silver and gelatine. The day or artificial light used in ordinary photography affects only the surface of the emulsion, whereas the X rays affect evenly the whole thickness. Greater intensities and contrasts can therefore be reached with thick layers, and it would be an advantage to coat the X-ray plates with a gelatine emulsion half a millimetre thick, but in this case the developer could not reach the deeper parts. To overcome this difficulty, films can be obtained now which are coated on both sides, to obtain greater densities. Special precaution has, however, to be taken in developing, fixing, washing, and drying such films, to prevent injury to the emulsion, which is very delicate, especially while soft.

Plates or films can be placed in red and black envelopes, or in special plate holders. With the former there is considerable risk of breakage if the weight of the patient's body presses unevenly on the plates. It should be made a rule that the coated side of the plate is always nearest the patient's body, because glass absorbs a fair quantity (some kinds up to 40 per cent) of X rays. If in some cases the film side, in others the glass side, were nearest the patient, it would also be difficult to find out afterwards which side of the negative corresponds with the right, and which with the left side of the patient. For this reason it is wise always to use lead letters L and R to denote the left and right side of the patient's body.

The plate has to be as near as possible to the object we wish to examine. For the spine, the kidneys, etc., it must be on the back of the patient, for the heart or the front ribs, it must be on the chest of the patient, and the tube at the back.

Plates must be stored in a dry place, sufficiently far away from the rooms where X rays are being used. If the dark room is immediately adjoining, it is necessary to line the *outside* of the cupboards or boxes in which the plates are stored with lead 2 mm. thick.

Intensifying or Accelerating Screens enable us to reduce the duration of an exposure to between one-eighth and one-sixteenth of the time which would be required without such a screen. It is therefore a great saving in the lifetime of the tubes, and a saving in the expense for current, to use them. They enable us to finish many difficult exposures in so short a time, that it is easy for the patient to keep motionless and to keep his breath. We can even make instantaneous exposures with the help of these screens, and provided that X rays of suitable penetrating power are used, the quality of the negatives

also becomes improved, because the contrasts grow greater and finer details become visible.

Exaggerated claims have occasionally been made about the degree of acceleration. It is pretty much the same with the various makes of screens, because the same chemicals are used in all of them. The acceleration varies considerably, however, with the quality of the X rays used. It is about four times as great for X rays with a half value depth of 2·5 mm. aluminium (i.e., whose intensity is reduced to one-half by 2·5 mm. aluminium) as when very soft rays are used, which require 0·5 mm. aluminium only. The maximum of details and contrasts will be obtained with fairly soft tubes, but the reduction of time of exposure is greatest with harder rays. Faint grain, however, begins to appear even with the best accelerating screens when the rays used are too hard, or when over-exposure takes place. With X rays requiring only about 0·8 mm. of aluminium half-value depth, the duration of the exposure is reduced to about one-eighth; with X rays requiring 4 mm. of aluminium, it is reduced to about one-twelfth, and negatives free from grain can be obtained with X rays of the latter quality.

The acceleration also varies with the intensity of the rays. With very weak rays, there is scarcely any acceleration, because they are insufficient to excite enough fluorescence. Fully 50 per cent of them are absorbed by the screen. With rays of great intensity, the gain will be about 20 per cent greater than when rays of low intensity are used.

The back of the accelerating screen should be nearest the patient, so that the X rays have to pass the screen first, before reaching the photographic plate. The X rays would be weakened if they had to pass first through the glass of the plate before reaching the screen. They have to be laid on the plate so that the film side of the accelerating screen is in contact with the film side of the plate.

When films are used, it is possible to use *two* accelerating screens, and to place the film between them. It would, however, be a mistake to suppose that the reduction in the time of exposure will be doubled by using a second screen. Nearly 60 per cent of the intensity is absorbed by the transformation of the X rays into fluorescence on the first screen, and the bromide of silver emulsion weakens the rays still further, so that the second screen cannot be reached by more than about 30 per cent, probably a little less, of the intensity which reaches the first one; moreover the rays have been filtered and become harder, so that a smaller percentage of them will be absorbed by the second screen. The fluorescence and the acceleration caused by the second screen cannot be more than one-third, probably only one-fourth, as great as that produced by the first screen.

Great care must be taken that there is no air space between screen and plate, because this would cause a blurred patch. It is best to use a good plate holder in which screen and plate are pressed together closely. The accelerating screens should not be larger than the photographic plate, otherwise the sharp edges of the latter would leave marks on the screen which would show on every negative made with it afterwards. It is

therefore necessary to have separate screens for all the various sizes of plates used.

The accelerating screens require very delicate handling. They must be kept scrupulously clean. Dust, scratches, marks from dirty fingers, or stains from chemicals used in developing and fixing negatives, cause marks to appear *on every plate exposed with such a screen.* They have to be dusted with a camel-hair brush, and after the exposure they must be stored in the box or envelope supplied with them, and a clean paper with a smooth surface should cover the sensitive side. It is best never to handle them on the same table on which developing and fixing dishes, etc., are placed.

The best **Distance between Anticathode and Plate** depends largely on the size of the plate to be used. As the intensity of the X rays diminishes rapidly with the increasing distance, we have to expose four times as long with a distance of 50 cm. as with one of 25 cm., and it would therefore be advisable to use as small a distance as possible, but this has the disadvantage that the organs appear distorted and considerably larger than they actually are. A heart may appear on the negative 4 cm. larger than it really is if the distance between the tube and plate is 60 cm. To obtain its shadow in practically natural size, it is necessary to use a distance of 2 metres. As this means an exposure nearly eleven times as long as with a distance of 60 cm., a compromise has to be made in most cases.

For thin objects, like the fingers, hands, or the lower arms, a distance of 30 cm. is sufficient. For a knee or a shoulder, 40 cm., and for a chest or pelvis of an adult of normal size, 60 cm. will be found best. With stout patients the distance may have to be somewhat greater. As the size of the plate is usually chosen in proportion to the area to be examined, it can be *made a rule that the distance between anticathode and plate should be 10 cm.* (4 in.) longer than the long side of the plate used; if the latter measures 10 by 12 in., the distance between anticathode and plate should not be less than 16 in.

The centre of the anticathode should always be above the centre of the plate.

The Patient.—It is necessary that the part of the body to be examined should be naked, to avoid the shadows of buttons, clothes, etc., and that it should be *as near as possible to the plate.* If, for instance, a negative of the *right* shoulder or hip joint has to be made, it is necessary to raise the *left* side considerably, so that the right side presses on the plate; if the kidneys have to be taken, it is desirable to raise the knees and the upper part of the body, that the spine may become convex, so that no air space is left between it and the plate.

It is necessary that the patients should rest comfortably so that they can easily keep quiet. A good negative cannot be obtained unless the part to be taken keeps motionless during the exposure. Small pillows or cushions, suitable rests for arms, legs, etc., will frequently help the patients to remain quiet in the desired position.

patients should begin to take aperients some forty-eight hours before the exposure is made. The bowels must be empty, and no solid food should be taken on the morning when the exposure is made.

Frequently it is necessary to paste small coins or pellets, with adhesive plaster, on to the nipples, the umbilicus, etc., so that they appear as landmarks on the negative, and allow the distance to be measured which some object has from a well-defined spot.

Compression.—To keep the part to be examined motionless, and partly also to reduce its thickness, compression is frequently used. A stout canvas band can be stretched across the patient, and sacks filled with sand can be attached on either side; or better, it can be stretched with the help of a roller and lever as tight as the patient can stand it, and can be fixed in this position with a clamp (see Fig. 34). Cylinder diaphragms attached to the boxes enclosing the tubes are also very convenient, for they can be pressed into the body, and a pneumatic cushion can be fastened on the lower rim, and can be inflated with double bellows.

The Exposure.—Before the actual exposure is made, and the plate is brought into the room, it is necessary to turn the current on, to see whether apparatus, tube, etc., are working properly (see also page 30), whether the current passes in the right direction, and whether there is a sharp division between fluorescent half and dark half of the tube. The pointer of the milliampère-meter should not fluctuate.

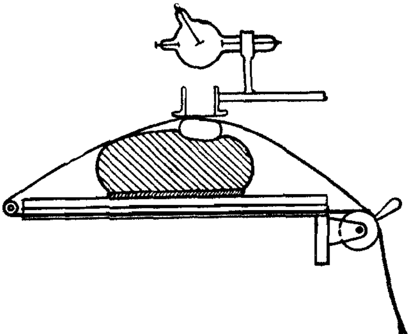


Fig. 34.

It is well to remember that the resistance controlling the speed of the motor should be *full in* before the switch for the motor is turned on. It is then reduced *gradually* till the motor reaches the desired speed. If the full current is turned on while no resistance is in the motor circuit, the motor may be burned out and destroyed. The frequency of the interruptions varies with the position of the crank of the rheostat controlling the speed of the motor. If a certain frequency is desired, the crank should be moved till it rests on the peg of the rheostat with which this frequency is obtained. For examination on the fluorescent screen, the frequency should not be less than forty per second to prevent flickering, for making negatives double this number of interruptions are frequently used.

The crank of the resistance controlling the strength of the primary current is moved till the desired number of M.A. through the tube is reached. This crank can be left in position.

It is also well to show the patients what will happen, so that they do not get frightened and attempt to move if the motor should make a little noise, or when the green light from the tube becomes visible. In many cases the patients should keep their breath during the exposure, and some instructions and a practical trial is desirable before the plate is fetched and the exposure made.

The **Duration of the Exposure** depends on the intensity of the X rays which reach the plate, and this depends on the electric apparatus, the penetrating power of the rays used, the distance, and the thickness of the object. The influence which the distance has on the intensity has been explained already, and a table about this will be found on page 127.

The duration of the exposure depends also on the result we wish to obtain. If merely the *outlines* of a bone have to be shown, to find a fracture or a dislocation, an exposure of one second may be ample; but if details of the *structure* of the same bone are required, to find a suspected disease, the exposure may have to last five or even ten times as long. The duration of the exposures for diagnostic purposes is usually expressed by the number of M.A. seconds.

The accurate quality or wave length of the rays which is best for various thicknesses and parts of the body, and the number of M.A. seconds required to obtain fully-exposed negatives, will be found in the tables on page 130. For beginners who have not yet the means to measure the penetrating power accurately with a spectrometer or an absorption meter, the number of M.A. seconds mentioned in the following lines will be some help when tubes with the equivalent spark gaps mentioned are used.

With the distances mentioned on page 66, with patients of about normal size, and a current of 5 M.A. through the tube, an exposure of about—

7 seconds, i.e., 35 M.A. seconds, will give good results for the wrists, lower arms, neck, feet, etc. Equivalent spark gap 12 cm.

12 seconds, or 60 M.A. seconds, will be required for the knee, upper leg, heart, or lungs. Equivalent spark 14 cm.

40 seconds, or 200 M.A. seconds, for the head, bladder, etc. Equivalent spark about 15 cm.

50 seconds, or 250 M.A. seconds, for stones in the kidney, the lumbar vertebræ, sacrum, etc. Equivalent spark about 13 cm.

50 seconds, or 250 M.A. seconds, for the pelvis or hip joint. Equivalent spark about 15 cm.

For stout patients the exposures mentioned have to last a little longer.

The numbers of M.A. seconds mentioned above refer to spark coils and gas tubes. If Coolidge tubes are used, they have to be doubled, and if interrupterless high-tension transformers are being used, the figures have to be multiplied by about 3 to 5, according to the construction of the individual apparatus.

If we increase the current from 5 to 10 M.A. by raising the strength of the primary current, the intensity will not be twice, but about four times, as great. If 10 M.A. can be used, the times mentioned can therefore be reduced to about one-third; with 20 M.A. to one-tenth. If an accelerating screen is used, they can be reduced to one-twelfth or one-fifteenth; if two accelerating screens are used with a film coated on both sides, the exposure can be reduced to one-twentieth of the times mentioned above.

If 10 M.A. are used instead of 2, the duration of the exposure for a pelvis can therefore be reduced from 100 to about 20 seconds. If an intensifying screen is used, the time can be further reduced to about 2 seconds. If the electrical apparatus is powerful enough to send 25 M.A. through the tube, the exposure without a screen can be reduced to about 1 second. The tubes will stand such currents without being injured. The pelvis is the part which requires the longest exposures. Useful negatives of the heart and some other parts of the body can even be obtained with one single interruption.

Most exposures are made with currents varying from 2½ to 10 M.A., according to the strength which the electrical apparatus will supply, and which will suit the tubes best, but to avoid the movements of restless children, the movements due to breathing, or the peristaltic movements, it is a great advantage if still stronger currents can be used, so that the exposures for any part of the body can be reduced to a small fraction of a second.

Some Hints for More Difficult Exposures.—A large number of exposures for the arms, legs, shoulders, heart, etc., are so easy, that most beginners succeed in obtaining fair and useful negatives at the first attempt. The chief difficulty is to place the patient and his limbs and the tube in such a position that the organs we wish to examine are well within the central rays emanating from the anticathode and above the centre of the plate, and to see that the patient does not move during the exposure.

There are, however, a fair number of difficult exposures, for which long and large experience is indispensable. The importance of using X rays of suitable penetrating power for these cases has been mentioned already. When this condition is fulfilled, it becomes possible to show stones in the kidney weighing about half a grain! The chemical composition of the stones, however, has an influence too. Stones consisting of uric acid only cannot be detected with X rays, because their specific gravity is the same as that of the surrounding tissues. They occur in the bladder, and even large stones, which are clearly visible with the cystoscope, cannot be made visible on the negative. Stones consisting of *pure* xanthin or cystin are invisible too, and for this reason it may happen that a stone exists, though even a technically perfect negative shows no trace of it. Experience has shown, however, that about 98 per cent of all stones in the kidneys, and 75 per cent of all stones in the bladder, will show. All the stones found in the kidneys and ureters usually contain some lime, and this has a greater specific gravity and makes them visible. Stones containing oxalate or phosphates are also clearly visible.

Phleboliths and some calcifications of glands may cause slight shadows, which may be mistaken for stones.

To make the alimentary tract visible, a meal of bismuth carbonate or *chemically pure* sulphate of barium should be taken. This is not only safer, but also cheaper, than the preparations of bismuth which were used for some time for this purpose. It is, however, important that it should be pure. It should be quite free from barium chloride, which is a violent poison, and also from barium carbonate, because the latter, though not poisonous itself, may be converted into the chloride by the hydrochloric acid of the stomach. Pure barium sulphate is a fine *white* powder.

The following is a good recipe which has been used regularly for many years in a large number of hospitals: 150 grammes of sulphate of barium, 20 grammes Mondamine (Maizena flour), 15 grammes cocoa, 10 grammes sugar, and 400 ccm. water, are used. This mash should be taken *while warm*; when cold it is too thick or lumpy to fill the finer cavities or folds of the alimentary tract.

The ureters are not visible, but to find out whether a stone is in the ureter or outside, a catheter, opaque to X rays, can be introduced first, and the shadows then indicate the exact position of ureter and stone. The gases in the bowels are transparent, and cause dark spots on the negative which may be misleading. The aperient helps somewhat, but a plain convex Luffa sponge, or an inflated rubber ball or cushion, may be pressed into the region of the abdomen to be examined, to disperse any gas bubbles (see Fig. 34).

If the bladder has to be shown, it may be filled with a 20 per cent solution of sodium bromide or potassium iodide. This seems to be better than the 5 per cent solution of collargol which was recommended formerly for this purpose.

If an exposure of the left kidney is being made, part of the spine, or of the lower ribs, should be visible on the plate, as a criterion. The appearance of the bones will show whether the penetrating power used, the duration of the exposure, and the development have been correct. As soft rays have to be used, the vertebræ of the spine will not become transparent, but ribs should show the fine details and tracings of bones. The lower half of the kidney appears as a faint shadow, crossed by the shadow of the 12th rib. It cannot, however, be made visible in all cases, in spite of technically perfect negatives. With children it is rare that the kidneys become apparent, because they contain too little fat. A good anatomical knowledge is indispensable too. Patient and tube have to be adjusted so that opaque organs like the heart or the liver are not in the way, because their shadows obliterate other organs. Stones of the gall-bladder, for instance, are difficult to trace on account of the liver. These difficulties can be overcome in some cases, by surrounding the neighbourhood of the parts we wish to see with air. In some cases an effervescent powder, or the injection of air through a catheter introduced through the rectum, may be sufficient. Nowadays air is also injected by means of sterilized sharp silver or steel catheters, which are pushed through the skin of the abdomen, after the spot which has to be punctured

has been painted with iodine and anæsthetized with cocaine. By means of double bellows, the abdomen is inflated, and even organs like the uterus have been made plainly visible by these means on a fluorescent screen or a negative.

That diaphragms with a fairly narrow aperture, in many cases cylinder diaphragms with suitable compression, have to be used with the more difficult exposures, goes without saying.

Stereoscopic Exposures.—Negatives or prints show us everything in one plane; we cannot, therefore, judge the relative position of the bones in case of a fracture, or the exact distance between the surface and a foreign body. But if we make two negatives of one object, and move the tube through a distance of 65 mm. between the two exposures, as indicated in Fig. 35 we can examine all the details in stereoscopic relief, and this is a great help in many cases. No complicated apparatus are required to make stereoscopic exposures

It is necessary that the first plate can be withdrawn after exposure and a fresh plate put in its place, without disturbing the position of the patient, *which must remain the same for both exposures.* Special plate holders enable us to do this.

The distance through which the tube is to be shifted depends on the thickness of the object, and on the distance between tube and skin; if the object is thin, or the distance great, we have to move the tube a greater distance. The tube holders are provided with a scale; the tube is fixed so that the anticathode is above the centre of the object to be taken, and the position is noted. If the tube has to be shifted 6 cm. altogether, we move it first 3 cm. to one side of this original position, and, after the first plate has been exposed, we move it to a distance of 3 cm. on the other side, and when the plate has been changed, make the second exposure. The plane in which the tube is to be moved, must be parallel to the plane of the plate, so that the distance between the anticathode and the plate is the same in both instances. The direction in which the tube is moved must be rectangular to the longest side of the object; if we take an elbow, for instance, the tube must be moved across, not parallel with, the arm.

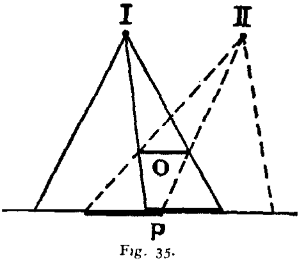


Fig. 35.

Large plates are examined in stereoscopes with reflecting mirrors, or else reductions of the plates can be examined in ordinary stereoscopes.

Development.—I do not intend to give here the instructions about development which can be found in all text-books on photography. Only a few hints which may be useful for developing X-ray plates will be given.

All the care and trouble and expense bestowed on the exposure may be

wasted unless the development is carried out with intelligence and skill, so that all the details which may be in the plate are really brought out. The contrasts are frequently very slight, and may disappear entirely by unsuitable or careless development.

The name of the developer used is less important than the fact that the operator understands it thoroughly. Each developer has its own peculiarities. In consequence of the great thickness of the emulsion of X-ray plates, several minutes elapse before the developer can penetrate to the deeper parts of the film, near the glass. It happens occasionally that fifteen or even twenty minutes may have to be spent to finish the development of a negative of the pelvis. This is about three times as long as the average time required to develop a landscape or a portrait negative. It is therefore important to select a developer which does not cause "chemical fog." I have always found hydroquinone a very good developer, because it can give great densities, and soft or hard negatives can be obtained at will by diluting it with water, or by adding bromide of potassium. Other developers are less affected by this and cannot be modified as much.

A *fresh* hydroquinone developer *does* cause chemical fog, but after two or three plates have been developed by it, this tendency disappears entirely. A hydroquinone developer which has been used already is therefore better than a freshly mixed one, and when stored in a bottle, *which is kept quite full*, the used developer does not deteriorate even for six months. It should be stored in a glass-stoppered bottle, and 12 to 15 oz. are poured out in the ounce measure. It will become weaker, and the quantity will become smaller after every plate developed with it. After finishing the development, only about two-thirds or one-half of the original quantity poured out is poured back into the bottle, and a sufficient quantity of newly mixed developer should be added, to make the bottle quite full again. In this way, the developer does not become exhausted and keeps useful for a long time.

The only fault of the hydroquinone developer is, that it is very sensitive to changes in temperature. It cannot be used in winter, unless the dark room, dishes, and solutions can be kept at a temperature of not less than about 60 degrees. A good formula for the hydroquinone developer is :—

Stock Solution, No. 1.		No. 2.	
Hydroquinone	15 grammes.	Caustic soda	15 grammes
Sodium sulphite	100 ,,	Water	900 c.cm.
Citric acid	5 ,,		
Potassium bromide	4 ,,		
Water	900 c.cm.		

Take 100 parts of No. 1 and 80 parts of No. 2, and add 100 parts of water.

Glycin is recommended by many X-ray workers. It is less sensitive to changes in temperature, and gives very clear negatives and fine details. Development can be prolonged very much without fear of producing chemical fog. A good formula is :—

Potassium metabisulphite	50 grammes
Glycin	30 ,,
Potassium carbonate	200 ,,
Water	180 c.cm.

This stock solution will keep well in a stoppered bottle for almost an unlimited time. Before use, it has to be shaken. For the usual development of single plates, 12 to 15 parts of water have to be added to one part of stock solution. For the tank development to be mentioned below, 50 parts of water have to be added to one part of the stock solution. The development will then be finished in 30 to 40 minutes.

The formula recommended by the manufacturers of glycin, and sent with each bottle, is more complicated, but gives very good results too.

Glycin is also the most suitable developer for the so-called tank development, which offers some advantages if a larger number of plates can be developed simultaneously. Place the plates in a clean tank, in an upright position, cover them with glycin developer, to which 4 or 5 times the usual quantity of water has been added, cover the tank with a lid to exclude the light, and examine the plates after about an hour. All the details which can possibly be brought out will be visible then, and there is no danger that the plates will be too dense. On the contrary, they will frequently be too thin. Perfect negatives can be obtained with the tank development, and it is the best method of bringing as much as possible out of somewhat under-exposed plates. Since no great experience is required, it can be left to assistants who are not yet experts in photography, without fear that good plates will be spoiled by unsuitable development.

Of the new developers, Neol (Hauff) is strongly recommended.

With large plates some skill is required to pour the developer over the plate so that the *whole* surface is covered by it rapidly. If this is not done, developing stains will appear, which spoil many otherwise good negatives. It is therefore wise to make it a rule first to pour water over large plates. When the surface has been well moistened, the water is removed and the developer poured over the plate. With prolonged development it is also important that the dishes should be rocked frequently. Special apparatus have been constructed to do this automatically with pendulum or electric motor.

It is fairly easy to control the development of negatives of hands, feet, arms, etc., because the pictures can be seen by holding the plate against the ruby lamp, but more experience is necessary to develop a negative of the thorax or pelvis. In these cases the picture is visible only at the beginning, and it is difficult to know when to stop. The development has to be continued in most cases till the picture shows through the plate when the glass side is examined.

Owing to the thick emulsion, the fixing also takes a longer time than with ordinary landscape or portrait plates. It is advisable to continue it twice as long as is necessary to make the bromide of silver on the glass side disappear; fifteen minutes is about the time required.

An acid fixing bath has some decided advantages over the ordinary hypo bath. It keeps in good condition much longer, and is therefore cheaper, and it has some clearing effect on the negative. A good formula for it is :—

Potassium metabisulphite	30 grammes
Sodium hyposulphite	250 ,,
Water	1000 c.cm.

If it is important to have a plate dry very soon, it can, after having been washed, be placed in 95 per cent alcohol for about 5 minutes. When well rocked

the alcohol combines with the water in the gelatin, and evaporates within 10 minutes. The same result may be reached with a small electric ventilator in about 15 minutes.

Intensification.—Many X-ray negatives will be thin and wanting in contrasts. If there are details, however faint, such plates can be improved by subsequent intensification. It is an easy process which can be carried out in daylight. The intensification not only increases the density, but alters the character of the plate somewhat by increasing the contrasts and making the picture harder. If, however, the details are wanting on account of great under-exposure, or unsuitable development, subsequent intensification will be no help. If the plates are to be intensified, it is important that they should have been thoroughly fixed and washed, otherwise stains might be produced. For intensification, the plates are placed in a solution of 100 grammes sublimate of mercury and 1600 c.cm. water. After they have a sufficiently milky appearance, they are washed and placed in a developer, or in a 10 per cent solution of ammonia.

The explanation of the numerous mistakes which can be made in the development and fixing of the plates must be left to the text-books on photography. I wish to mention only a few points which are peculiar to X rays. Some fogginess of the plate cannot be avoided. It is dne to secondary and scattered rays, but it might also be increased by storing the unused plates so that they can be reached by faint X rays. As the development lasts considerably longer than with ordinary photography, there is greater risk that fogginess may be caused if the developer should be too strong, too warm, or too cold. If the emulsion begins to frill near the edges, it contains too much caustic potash.

Examining Negatives.—It is a mistake to hold a negative against the sky to examine it. The bright light at the side of it dazzles the eyes and prevents us from seeing many fine details. It is better to place a porcelain dish or a white paper on a table, and while holding the negative at an angle of 45 degrees, we can examine it with the light reflected from the white surface.

If the room is darkened, we can see considerably more. The window can be covered with a black board with an opening, in which carriers can be placed to hold negatives of different sizes. On the window side of the opening a milk glass plate has to be fixed. Better still than this is a viewing box, with a few incandescent lamps behind the milk glass, and a small rheostat to vary the candle power of these lamps. It makes us independent of daylight and its fluctuations. To detect the finest differences in the shades, it is necessary that the intensity of the light should be adapted to the density of the shadows, and that the light should be neither too bright nor too dull. It is frequently an advantage to examine negatives at a distance of about ten to fifteen feet with a good opera or field glass.

The front of the viewing box should be vertical, not desk-like. It enables us then to make reductions and lantern plates of the negatives, by placing a camera on a tripod at a suitable distance from the viewing box. With the

present prices of all materials, it is cheaper and frequently less trouble to give the patient or his doctor a diapositive of considerably reduced size, than a full-sized paper print. It is also well known that thin negatives, with weak contrasts, can frequently be considerably improved by making a reduction while the negative is illuminated with a comparatively weak light, and the diapositive developed so as to obtain hard contrasts.

THE PRACTICAL APPLICATION OF X RAYS FOR THERAPEUTIC EXPOSURES.

The advantages which diagnosis derived from the discovery of X rays surpassed the most sanguine expectations, but the benefits conferred on mankind by their therapeutic applications have nowadays become equally great, and are still growing from year to year.

In a large number of diseases of the skin, the results are so excellent that the use of X rays in their treatment is growing steadily. In gynæcology, in the treatment of excessive hæmorrhage due to the approaching climacterium or to fibroids or myomata, 100 per cent of cures, *without a single failure or mishap*, are claimed and admitted, and this is achieved by exposures to X rays lasting no more than 1 to 2½ hours altogether, which scarcely interferes with the daily occupations of the patients. Even in some deep-seated malignant diseases, in most sarcomas, and in carcinomas of the uterus, the results obtained are now already as good as those obtained by the best surgeons, though the treatment of these cases with X rays is as yet *in its infancy. Of those cases which are considered past surgical help, up to* 12 per cent could still be cured by X rays, and in the majority of the remaining cases pain can be greatly relieved and the progress of the malady retarded.

Good results have also been obtained in the treatment of some internal diseases like leukæmia, certain kinds of tuberculosis, asthma, etc. (see page 110).

The use of the X rays for diagnostic purposes can be learned even by nurses in a few weeks. If any mistake has been made with the exposure, it can be repeated several times without much risk of doing harm. For therapeutic exposures, however, this is different. The doses required to produce the biological changes are fifty to several hundred times as large as those required for diagnostic purposes. The effects which the X rays produce cannot be seen for several days, and harm is sure to be done when the correct dose is considerably exceeded, and, in a few cases, even when it has been too small. The difficulty, the art, and the skill of the treatment consist in applying to the organ we wish to affect a dose sufficiently great to produce the desired effect without injuring other organs.

To be successful with therapeutic exposures, especially those for deep-seated malignant diseases, considerable knowledge, skill, and experience are

therefore required to master the correct quality, dose, and direction of the X rays; but on the other hand, medical men can certainly learn it in as many months as it will take years to learn to perform efficiently some of the surgical operations which can now be replaced with equally good, or even better, prospect of success by exposure to X rays.

X rays act like a poison on animal tissues. If doses of sufficient strength are applied, cells become irritated, blisters, inflammations, and changes in the blood are produced and the cells may even be killed. Small animals exposed to a certain dose invariably succumb.

That we may employ them as a curative agent is due to the fact that the susceptibility of different groups of cells varies a good deal. Young and rapidly growing cells are much more susceptible to this poison than older cells in which metabolism has become less active. Hyperæmic tissues are more susceptible than anæmic tissues, spermatozoa and ova may be killed, and in embryos or in growing seeds of plants the rate of growth may be retarded or permanent injuries may be produced by doses of these rays, which are not yet sufficient to leave any visible effect on older cells. The cells of malignant diseases may be killed, or at any rate paralysed, by doses which will produce only a temporary slight inflammation of the skin.

It is well to note at the beginning that:—

The biological effects are *in proportion to the quantity of X rays which have been absorbed*, and secondly that:—

A weak dose irritates or appears to stimulate, a medium dose paralyses, and only a strong one kills the cells.

For a long time it was definitely asserted that a weak dose stimulates the individual cells to increased growth, but this is much disputed now. Holzknecht of Vienna is of opinion that every dose of rays, no matter how small, acts detrimentally to the individual cell, but if it is not strong enough to kill the cell, the latter will recover. If now a small dose is applied to a growth, the most diseased cells only will be destroyed and the others can, when the irradiation has ceased, recover and expand at the expense of the dead ones, thus giving an impression of increased activity.

There are many analogies with other poisons, and experiments on growing plants and animals, and some clinical experiences have brought some proof that this is so. The fact of the apparent stimulation now seems to be accepted by the majority. The difficulty is, however, that the exact doses which stimulate various organs without doing harm are not yet known. It is therefore not yet possible to use X rays intentionally for stimulation. The stimulation is only temporary, and a dose which scarcely begins to stimulate certain organs, like muscles, to greater activity, is already fatal to organs like the ovaries or testicles.

The quantity which is absorbed depends on the intensity of the rays reaching the object, on the length of time during which they act, on their quality, and on the size and density of the object. As it would be most difficult to measure the rays which enter and which leave the body, and the cubic space on which they acted, it has become the custom in medical

practice to reckon as unit the dose which produces a certain fairly well-defined effect on the skin, which is called erythema (see also page 49).

The Dosage for Therapeutic Exposures.—The dose which produces an erythema is the unit for all therapeutic exposures. Every new tube has to be tested or "calibrated" to find out in what time an erythema dose can be produced with it under the conditions which are to be used, i.e., with the distance, strength of current, filter, etc., before it is employed for exposures on patients.

If a "standard" tube is available of which the exact time required to produce an erythema is known already, this calibration is easy. It can be made in the manner described on pages 51 to 56. If no such tube is available yet, or if a new filter or apparatus has to be used, the time in which an erythema will be produced can be found out *approximately* with some experiments with chromo radiometers. It has, however, to be remembered that the value of the tints of the Sabouraud pastille or the Kienböck strips vary with the quality of the rays and the filter used.

With filters of :—

0	0·5	1	2	3	4 mm. aluminium,
10	27	35	50	65	70 x Kienböck, or
1·0	1·6	1·8	2·1	2·5	3 Teinte B's Sabouraud

are required to produce an erythema. Should, for instance, 5 x on a Kienböck strip be achieved in 50 seconds under an aluminium filter 0·5 mm. thick, this would mean that the 27 x required for the erythema dose will be reached in $\frac{50 \times 27}{5} = 270$ seconds, but if it should take 50 seconds to produce the 5 x under an aluminium filter 4 mm. thick, it will take $\frac{50 \times 70}{5} = 700$ seconds, or 11·6 minutes, to reach the 70 x under this thicker filter.

For this experiment Kienböck strips are preferable, because they can be exposed *on* the surface of the phantom, and are thus under the influence of the scattered rays too, and there is no need to find the position half way between focus and skin, as with the Sabouraud pastilles. After the duration of the exposure has thus been found approximately, it can be found accurately on patients without risking a serious over-exposure or too great an under-exposure. The epilation dose, for instance, can be found out by exposing the arm or leg of a male patient. How the erythema dose can be determined empirically on a patient to be sterilized for excessive hæmorrhage without fear of injuring the patient is described on page 94. The manufacturers of the apparatus can give approximately the time in which the erythema dose will be produced with various distances, filters, etc., with the particular apparatus.

In addition to the surface dose, it is important to know the *percentage of the surface dose which is effective at various depths*, and this varies with the

quality of the radiation as determined by the voltage of the apparatus, the distance between anticathode and skin, and the size of the window on the skin through which the rays enter. It will vary a little even between one tube and another under otherwise similar conditions. How it can be determined with the phantom has already been explained on page 54, and tables showing the variations due to increasing distances and apertures of the windows will be found on pages 131 and 135–138.

To obtain a homogeneous irradiation, the distance should be chosen large, but as the duration of the exposures increases rapidly with increasing distances, compromises have to be made. The distances which have been found best for various purposes will be mentioned later on.

The Treatment of Diseases of the Skin.—Soft rays are no longer used even for the treatment of skin diseases. Tubes with equivalent sparks of about 20 cm., and aluminium filters 1 to 3 mm., in a few cases even 4 mm. thick, are now most frequently used. If the action of the rays is desired *on* the skin only, or not more than 1 mm. below it, filters are not absolutely necessary when fairly hard tubes are used; but if the action must extend 1 or 2 mm. below the skin, filters of about 1 mm. aluminium should be used. If the action is desired 3 or 4 mm. below the skin, filters of 2 or 3 mm. aluminium are better to stop the soft rays, which would otherwise be absorbed by the skin and might cause an erythema before the layers 3 mm. below the skin have been reached by the desired dose.

The difference which these filters make can best be shown by the experience gained in epilation: when *no* filter is used the *full* erythema dose has usually to be applied to cause all the hairs to fall out; when a 3 mm. aluminium filter is used, 0·6, i.e., little more than one-half of the erythema dose is already sufficient to produce complete epilation, and *no inflammation* or reaction whatever will appear on the skin. The duration of the exposure will be three times as great as it would be without a filter being used, but in most cases this will be amply compensated by the absence of any inflammation.

On the other hand, filters which are thicker than 4 mm. aluminium should not be used for skin diseases, except in cases of malignant diseases extending lower down, as otherwise rays of too great a penetrating power would reach the patient, and healthy organs lying deeper down would be exposed to unnecessarily large doses.

Even Distribution of the Intensity over the Diseased Area is of great importance. If, for instance, in epilation for ringworm a small patch should not be reached by a sufficient dose to cause the hairs to fall out, the disease is most likely to spread again from this patch; or, if in attempting to remove a lady's beard, only a small part of it remains, or if part of the skin should become bronzed, the cosmetic improvement would be entirely lost. Analogous conditions exist with many other diseases. It is rather difficult, or impossible, to correct such errors with subsequent exposures,

because the sensitiveness of the skin has become changed by the first exposure and remains in a very uneven condition for several months.

Unless the diameter of the diseased area is quite small, it can be exposed to a dose of uniform intensity only if it is spread over a circular concave area, with the anticathode in the centre of it, but such conditions are very rare with skin diseases. If the diseased area is spread on a fairly level surface and the central ray falls perpendicularly on it, the middle of the area receives a greater intensity than those parts which are some distance away from this spot, partly because the distance which the rays have to traverse becomes greater, and partly because rays striking an object obliquely have a smaller intensity than those striking it perpendicularly. The smaller the focus skin distance, the greater will be these differences, as is evident from the illustration (Fig. 36). The distance **a b** is shorter than **a d** by **b d**, but when the focus skin distance is increased, the difference between the two is **h d** and is smaller.

In Fig. 37 the difference of distance of the two rays due to increasing obliquity becomes still more apparent.

Fairly even irradiation could be achieved by choosing large distances, but the duration of the exposures is thereby increased so considerably that the inconvenience and expense become too great, and with convex surfaces, like the head, not even the longest distances would give satisfactory results with one single exposure. To obtain a sufficiently uniform irradiation of flat surfaces of larger area, or of convex surfaces, it has been found that the distance between anticathode and skin should be *at least twice as long as the diameter of the diseased area.* But if this diameter exceeds 15 cm., it is better to divide the area in several smaller fields, to be exposed separately, than to have to increase the focus skin distance beyond 30 cm. The total time required for *one* exposure with more than 30 cm. distance will be considerably greater than the sum of several exposures with only 20 cm. distance each.

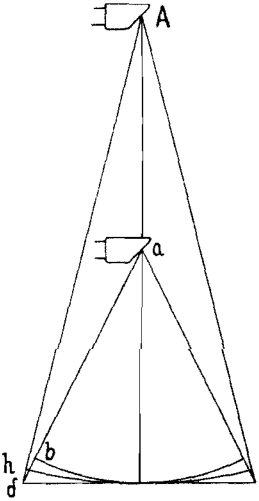


Fig. 36.

It is not advisable, moreover, to use too many different focus skin distances because this would make it necessary to calculate the duration for each exposure according to the distance used. It is more convenient to u not more than two distances: 20 cm. for areas not exceeding 10 cm. diameter, 30 cm. distance for areas between 10 and 15 cm. diameter. T intensities obtained nowadays with good modern apparatus are so great th

the exposures can be finished in a reasonable time even if the focus skin distance is 2 to 4 cm. greater than would be strictly necessary. The loss is small compared with the advantage of obtaining greater uniformity in the intensity over the whole area and the convenience of having to

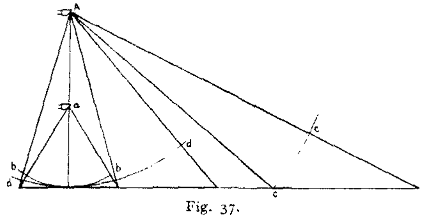


Fig. 37.

use not more than two different durations of exposure to produce the erythema dose.

If the diameter of the area exceeds 15 cm., it is divided into several fields, each of which receives a separate exposure. It is best to map these out carefully, and to mark the outlines with coloured pencil on the skin, or to make a plan on paper to find the points which should be struck

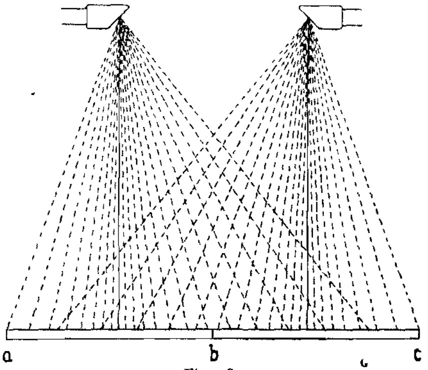
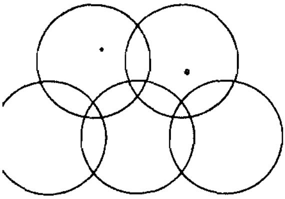


Fig. 38.

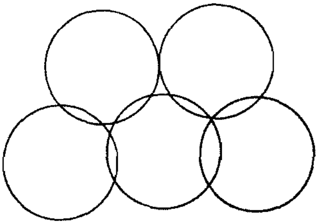
perpendicularly by the central rays. These spots are marked. It is a help if a wooden rod of suitable length can be attached to the tube box so that it is centred, and projects in the direction of the central ray. The tube box is then shifted till this rod touches the spot through which the central ray should pass perpendicularly. The rod is then removed before the exposure begins.

Other contrivances exist serving the same purpose: for instance, a telescopic centimetre rule, described on page 85, or a tripod, with 3 rods converging in the centre, may be attached to the tube box; if the rods are made of thin transparent wood, such a tripod may even be left in position during the exposure, as the rods absorb very little of the rays.

Formerly, it was attempted to expose rectangular areas about 8 × 8 cm. wide and the adjoining ones were protected with lead rubber. It is not possible to obtain satisfactory results in this way, because the frontier lines will either receive double exposures or no exposure at all. It is a much better plan to let the exposures overlap over the adjoining areas. The intensity of the rays diminishes gradually the further away they are from the central rays, but the difference is made up because these parts receive a second or third exposure by the rays overlapping when the adjoining area is exposed (see Figs. 38–40). A circle of 25 cm. diameter may be divided into 5 areas as indicated in the illustrations. Even the surface of convex objects like the



ABOUT RIGHT.
Fig. 39.



WRONG
Fig. 40.

head can be subjected to sufficiently homogeneous intensities in this way. It can be mapped out in 5 circles of about 10 cm. diameter each and exposed with focus skin distances of 20 cm. If the circles overlap sufficiently, complete epilation can be achieved without causing any inflammation.

To produce permanent epilation, it seems to be necessary to irradiate each part three times with intervals of a few weeks between the sittings. For the treatment of *malignant* diseases of the skin, the healthy part surrounding the diseased area is efficiently protected with a mask of lead, or lead rubber, and 120 to 230 per cent of the erythema dose is then applied to the diseased area. A high percentage of permanent cures is being obtained with X rays in this class of skin diseases.

The dermatological clinic of the University of Zurich reports that cases of rodent ulcer were successfully cured by using tubes with an equivalent spark of 33 cm. aluminium filters, 3 to 4 mm. thick, and by giving 7 Sabouraud Teinte B doses to each case, which correspond under the above conditions to about 2·3 erythema doses. When weaker doses were used the result was not permanent and many cases became recidive.

For the **Dosage in the Treatment of Skin Diseases,** Sabouraud pastilles are frequently used. The difficulty that these pastilles do not indicate fractions, or multiples, of the erythema dose can be overcome if the distance between the pastille and the skin is chosen suitably larger or smaller than that between focus and pastille. If the distance between skin and anticathode is 20 cm., the epilation dose will be obtained when a Sabouraud pastille exposed at 10 cm. from the anticathode assumes Teinte B. But if a pastille is exposed at this distance, and the distance between it and the skin is *increased* to 15 cm., the skin will have received only two-thirds of the epilation dose when the pastille assumes Teinte B. By varying the distances suitably, fractions of the epilation dose can be measured. On the other hand, by making the distance between the pastille and the skin *less* than the distance between anticathode and pastille, multiples of the epilation dose can be measured; the figures will be found in the tables on page 131.

After sufficient experience has been gained as to the time in which the epilation or erythema dose will be produced under given conditions of tube, strength of current, distance, filter, etc., the pastilles can be dispensed with, and the dosage by length of time, as explained on page 50, can be used for the treatment of skin diseases too.

THERAPEUTIC EXPOSURES OF DEEP-SEATED ORGANS.

Professors Krönig and Friedrich of Freiburg, and Seitz and Wintz of Erlangen, have taken great trouble to measure accurately the doses of X rays which will cause certain biological changes, like the sterilization of the ovaries, or the shrinking and disappearance of various kinds of malignant tumours. In Erlangen, they found that if the dose which will produce an erythema is expressed by the figure 100, there will be required:—

100 per cent to produce an erythema.
34 per cent to produce sterilization of the ovaries.
60 to 70 per cent to make a sarcoma disappear.
90 to 110 per cent to make a carcinoma disappear (see table 25, page 139).

The doses which were found independently at Freiburg do not differ materially from those found in Erlangen.

Though it is denied now that it is possible to determine a dose which will kill *all* carcinoma cells, or which will have a *uniform* effect on carcinomas appearing in different parts of the body, it is undoubtedly a great advance that the doses, with which definite results have been obtained in thousands of cases, can be measured, and expressed in such a manner that others may apply the same dose and profit by the large experiences which have already

The difficulty consists in applying doses of the strength mentioned above to organs which are 6 to 10 cm. below the surface, *without injuring the skin, the superficial layers, and the parts surrounding the organs to be treated.* To make a carcinoma of the uterus disappear, a dose quite as strong as that which will produce an erythema on the skin has to penetrate to a depth of 8 to 10 cm. below the surface, and owing to the greater distance from the anticathode, and the unavoidable absorption taking place in the supervening tissues, the X rays are bound to become steadily weaker before they arrive at these depths. To apply such strong doses 6 to 10 cm. below the skin, without injuring it, it is necessary to use:—

1. Electrical apparatus and tubes producing a large quantity of very hard X rays.
2. Suitable filters, and a suitable distance between anticathode and skin, so that a high percentage of the surface dose will be available 6 to 10 cm. below the surface, and
3. Cross fire.

The Apparatus.—Most of the apparatus required for therapeutic exposures of deep-seated organs have been described already under spark coils, interrupters, tubes, etc., so that only a few special features have yet to be mentioned which become necessary when the E.M.F. used rises to 160,000 or 200,000 volts.

Instead of the thin wires and cables which are usually employed for connecting the coils with the X-ray tubes, it is necessary to use polished brass tubes of about 10 mm. diameter, with balls at the ends, to avoid sharp edges from which brush discharges start.

Even with this precaution, ample ventilation of the room is yet more important than when X rays are used for diagnostic purposes, otherwise the assistants and patients will suffer. The patients will more readily become victims of the X-ray sickness (to be mentioned later on) in a stuffy atmosphere, than in a well-ventilated room, and the assistants suffer if they have to spend many hours every day in a room with the irritating smell of ozone and nitric acid gases.

It is also obvious that better protection is necessary with X rays of the greatest penetrating power than with those of medium or low penetrating power used for diagnostic purposes. Wherever possible, the protecting screens between operator and patient should reach from floor to ceiling, or should project at least 60 cm. above the head and 60 cm. on each side of the usual position of the operator's body. The screens should be lined with lead not less than 3 mm. thick, and the windows should consist of lead glass, with lead equivalent of not less than 2 mm. The protecting box enclosing the tube has to be lined with thicker material too. When Coolidge tubes are used, the box must enclose them all round, and the openings left for the necks of the tube should be closed by movable collars of lead glass or other protecting material of suitable diameter, so that no open space exists round the necks of the tube.

If the adjoining rooms, or the rooms above or below the X-ray room, are regularly occupied, and if the X-ray apparatus is to be used several hours every day, it is necessary to line the walls and the ceiling and floor with protecting material.

The tube stands must be specially adapted to the work. They must be heavier, and have larger bed plates, than the usual stands, so that they can carry the greater weight of the protecting box, and that suitable compression can be employed with them. As little metal as possible should be used in the neighbourhood of tubes connected with 200,000 volts, and so the tube box has to be suspended in a fork of wood of suitable strength.

Attached to the tube box is the filter, and below this cylinders or pyramids of wood lined with lead glass or rubber, of suitable lengths, apertures, and shapes, can be fixed, which control the correct distances between

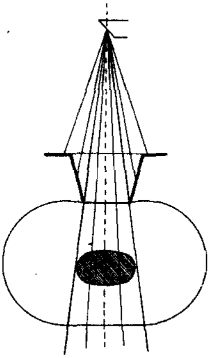


Fig. 41.

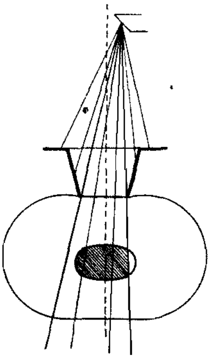


Fig. 42.

the anticathode and the skin of the patient. A thin piece of wood closes the lower end of these diaphragms, partly to absorb any secondary rays which may start from the metal of the filter, but chiefly to keep the surface of the patient's body, which is within the diaphragm, flat, so that it cannot bulge inwards. If any elevated central part were to project into the aperture of the frame, it would come nearer to the anticathode than the edges and would receive an overdose owing to the shorter distance. The even compression which can thus be applied slightly reduces the depth of the object to be treated; moreover, it makes the skin anæmic, and so reduces its sensitiveness to X rays by as much as 50 per cent. Under a 4 mm. aluminium filter a non-compressed skin will develop an erythema after it has been reached by little more than 3 Sabouraud Teinte B doses; with a well-compressed skin, 4½ to 6 such doses have to be given to reach the erythema dose. It helps also to prevent the patient from moving, and shifting the direction of the cone of rays.

It is important that the focus of the anticathode should be exactly above the centre of the diaphragm. In the illustration the dotted line indicates the axis through the centre of the diaphragm, and the anticathode should be centred so that the central ray runs along this line. Fig. 41 shows the distribution of the rays over the area to be examined or treated with X rays, when the focus of the anticathode is in the centre above the diaphragm. Fig. 42 shows the result when it is not in the centre.

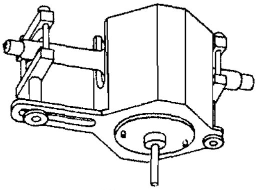


Fig. 43.

A simple contrivance helps to centre the tubes correctly without even switching the current on. A metal disc, which fits the lower aperture of the tube box, and which can be fastened to it temporarily, carries a brass tube. The X-ray tube will be in correct position when the focus of the anticathode, which can easily be recognized by its somewhat matted surface, appears in the centre of the image reflected by a little mirror placed below this brass tube. The X-ray tube is fastened in this position by screwing home the nuts on the clamps of the tube carrier.

This little apparatus can equally well be used to measure the exact

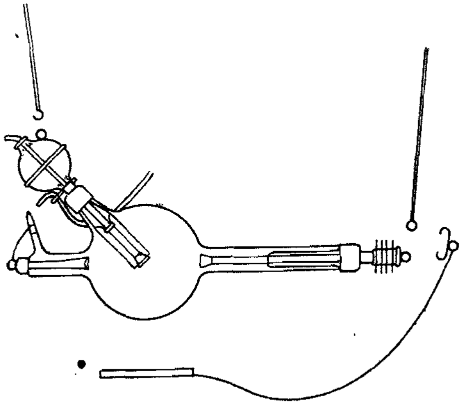


Fig. 44.

distance between anticathode and skin. For this purpose, a second brass tube slides telescopically over the first one, and a cm. scale engraved on the latter indicates the distance. Moreover, as this telescopic tube indicates the direction of the central ray, it can be used to find the position and inclination

to be given to the tube box so that the central ray enters the desired spot and in the desired direction.

There is a danger that one may forget to place the filter in position before the exposure begins. With the strong doses required for this therapy, this would have the gravest consequences. A simple contrivance has been suggested to avoid this risk. All tubes are provided with rings at both ends, and the cords have hooks, to be attached to these rings. If one of the cords is provided with a ring too, and *all* the filters with a short silk cord carrying a double hook at its end, as shown in the illustration (Fig. 44), the connection cannot be made without this double hook, and the operator is thus reminded of the filter if it should have been forgotten. Different metals can be provided with silk cords of different colours—aluminium white, copper red, zinc black, etc.

With currents of some 180,000 volts or more, and highly exhausted tubes with equivalent spark gaps of about 40 cm., a bundle of X rays can be produced in which the waves of greatest intensity have a length of about 0·10 Å.U., and which is very rich in rays of this great penetrating power. When they are filtered through 0·5 mm. of zinc or copper, the rays of soft and medium penetrating power are absorbed so far that the patients are subjected only to rays which are "homogeneous for biological purposes" (see pages 10 and 11).

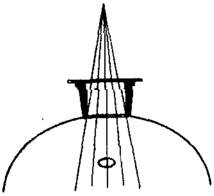


Fig. 45.

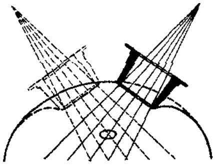


Fig. 46.

Concentration of the Rays through various "Windows," or "Cross Fire."—Even the hardest rays which can be used are weakened so much by increasing distance and by absorption, that if 25 per cent of the intensity prevailing at the surface penetrates to a depth of 10 cm. below the skin, this is considered to be a good ratio with a distance of 23 cm. between anticathode and skin and an area of about 50 cm^2. If we were to continue the exposure through the *same part* of the skin, as shown in Fig. 45, till a carcinoma of the uterus had received 100 per cent of the erythema dose, the skin would have received about four or five times as much in the meanwhile, and a severe burn with ulcers would be the result, which might be almost as bad as the malignant disease, and equally painful. Even the 34 per cent of the erythema dose required for the sterilization of the ovaries would produce

This difficulty can be overcome if the total quantity of X rays to be administered is not allowed to enter through the same part of the skin. It the object to be treated is 6 cm. or more below the surface, a "cross fire" can be directed on it from several points of the surface, as indicated in Fig. 46, by altering the position of the tube and of the diaphragm, after one part of the skin has received about 90 per cent of the erythema dose. If a sufficient number of windows are used, we can apply at a depth of 10 cm. doses even greater than the erythema dose without exposing any portion of the skin to more than 90 per cent of the erythema dose.

The Number and Size of the Windows to be used depend on the strength of the dose we intend to apply to the diseased organ, and on its position, and on the ratio between the surface intensity and the effectual intensity available at the depth. If the latter is, for instance, 20 per cent of the former at a depth of 10 cm., and we wish to apply 100 per cent of the erythema dose to a uterus situated at such a depth, we must use five to seven windows. Three of these can be given through the abdomen, a similar number through the back, one might be given from each side, or one through the vulva. With the ovaries, the 34 per cent of the erythema dose required to produce sterilization can easily be obtained through two windows for each ovary.

Between the adjoining windows, a space of 3 to 4 cm. should be left free, otherwise tissues which are only 1 or 2 cm. below the surface may receive an overdose, if the cones of the rays overlap so near the surface already that they have not yet been weakened to any large extent by absorption and the greater distance.

The Aperture for the Windows should be chosen so that the cone of rays is large enough not to miss even a small target, like the ovaries, when the direction of the tube has been carefully adjusted, and to include the whole of a malignant tumour, but it should not be unnecessarily large, partly to enable us to find room for a sufficient number of windows on the surface of the abdomen or the back, and partly to avoid exposing an unnecessary quantity of tissues, blood, etc., to the X-ray toxin.

The tendency is, however, to use larger windows. In the first years, when the treatment of excessive hæmorrhage with X rays was begun (1906 to 1910), a large number of windows (up to 50 !) were used occasionally, because with the tubes and apparatus available in those years the percentage depth dose was very small. To find room for them, the apertures had to be correspondingly small (about 20 cm^2.), which resulted in small targets like the ovaries frequently being missed, whilst few tumours can be included entirely in such small cones.

For the treatment of malignant diseases, the ideal would be to expose the whole abdomen to a uniform dose of sufficient strength to make the malignant tumours shrink. Technically this can be done by giving four exposures with 60 cm. distance, one from the front, the second from the back, and one from each side; but when the carcinoma dose is applied to the whole abdomen, the injuries to the blood, etc., become so large that patients are in

Experiments on mice and other animals prove that comparatively large doses produce no visible harm to the general health when administered through a small aperture of 8 mm. diam., whereas when the *whole body* was exposed to only one-tenth of this dose, *all* the mice perished, some of them within three hours. In the year 1912 or 1913, a few patients, who were beyond help, were exposed with their consent to large doses over a large area, with the result that the tumours shrank, but the patients died from the effects of the X-ray toxin.

A compromise has therefore to be made. Windows of 6 × 8 cm. have proved to be very convenient in a large number of cases. Three of these find room, with the necessary intervals, across the lower part of the abdomen of patients of normal size. In the case of stout patients, the apertures may be increased a little, because it is more difficult to find the exact position of the ovaries, etc. Apertures of 9 × 9, or even 9 × 12 cm., have to be used if the size of the tumour, or a large distance between anticathode and skin, should make it necessary. Both ovaries can be exposed simultaneously from the back with a window of 8 × 10 cm. at a distance of 30 cm. Some doctors prefer windows with an aperture of 80 or even 150 cm^2., with focus skin distances of from 30 to 40 cm.

The percentage of the rays arriving at the depth depends to some extent on the diameter of the cone of rays entering the body, i.e., on the size of the window, because the greater it is, the more "scattered" rays will be available. With a distance of 23 cm. between anticathode and skin, we may obtain 20 per cent of the surface dose at a depth of 10 cm. when the diaphragm has an aperture of 50 cm^2.; when the opening of the diaphragm is increased to 80 cm^2., the intensity of the rays will rise to 23 per cent, and when the aperture is increased to 150 cm^2. it will rise to about 25 per cent of the surface dose (see table No. 21 on page 135).

The losses due to increasing distance and to absorption by the tissues to be traversed—the latter vary with the quality of the rays used—are known, but the influence of the scattered rays makes it impossible to find by calculation the intensities prevailing at various depths. They have to be measured empirically with an Ionto quantimeter or Kienböck strips, which may be exposed in a suitable phantom, or introduced in cavities like the rectum or vagina of the patient. The following figures show the differences existing between calculation and actual measurements :—

Depth below surface in cm.	Making allowance for absorption and increasing distance, the intensities should be :	Actual intensities with windows of :		
		18 × 24	9 × 12	5·7 × 5·7
0	100	100	100	100
5	32·1	45·5	42	40·3
10	10·7	30	24·8	22·6

Correct Distribution of the Dose over the Diseased Area.—The dose required to produce sterilization of the ovaries is so small that no harm will be done to the surrounding organs if it should be exceeded 100 or even 150 per cent. The matter is totally different when carcinomas have to be treated. Fully 100 to 110 per cent of the erythema dose is required to make these tumours shrink, and 140 per cent of the erythema dose may already produce injuries to the bowels so severe that in a few cases they have proved fatal.

The result and success of the treatment depends on supplying to the diseased area a dose of sufficient strength, without injuring any other parts, and this depends to a large extent on whether the direction of the cones of rays, and the diameter of them, have been correctly chosen. Great knowledge, thought, and skill are required to do this, and a high percentage of the failures with X-ray treatment is undoubtedly due to mistakes which have been made in this respect.

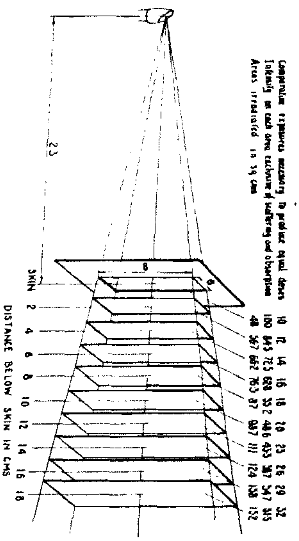


FIG. 47.

In many cases it will be a great help if a sketch of the cross-section of the patient's body is made on paper in natural size, and the position and size of the tumour is marked on it as accurately as this can be done. Several drawings of the cones of rays, with different sizes of windows, should be made on thin celluloid sheets, or on transparent paper, and the central ray, the distance, and the outlines of the cones, should be marked as indicated on Fig. 47. By placing one of these transparent drawings over the sketch of the cross-section of the body, we can find out whether the diameter of the cone is large enough to cover the whole of the diseased area, or whether the size of the window, or the distance between anticathode and skin, should be increased, and what position the tube should have. When a protractor is placed on the drawing, the angle which the central ray should form with the perpendicular, and the distance from well-known landmarks, like the umbilicus, etc., to the point where it should enter, can be found out. This point is then provided with some mark on the patient's body, and a protractor should also be fixed on the tube stand so that the tube box may be set at the proper angle. The illustration (Fig. 48) shows what a great difference a

slight alteration in the inclination of the tube box may cause to the organs included in the cone of rays.

By placing a second transparent drawing over the first, to find the best direction to be given for the exposure through a second or third window, we can see where the cones begin to overlap, and which organs beside the tumour will be subjected to the second or third exposure. The direction of the cones has to be chosen so that the *same part* of sensitive organs, like the bowels, should not be included in the cone of rays from too many windows.

When the best position for all the windows has been found out, the intensity of the doses to be given to each window has yet to be considered, so that the *sum* of all exposures reaches the intensity we wish to apply to the diseased organ. The further the X rays penetrate through the tissues of the body, the more uneven will become the distribution of the intensity. This is due in part to the losses caused by the greater distance, but chiefly to the influence of the scattered rays. Their intensity is greatest near the central ray, but diminishes with the square of the distance as the distance from it increases. This intensity also increases within certain limits, with increasing depth. Instead of being distributed evenly over spherical surfaces having their centre at the focus of the anticathode, the surfaces of even intensity gradually assume shapes as shown in Fig. 49, but the shape of these curves changes with the penetrating power of the rays, with the diameter of the cones of rays used, and with the distance between the anticathode and skin.

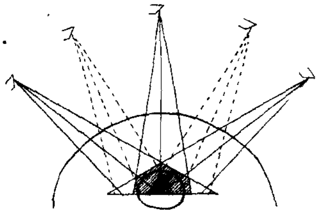


Fig. 48.

Tables are available, which have been compiled in the Institute for Medical Physics in Frankfurt, from the results of measurements of the points of equal X-ray intensity in the body. The results have been plotted on diagrams as shown, and the lines represent the edges of surfaces of equal intensity, while the figures denote the percentage depth dose. Various diagrams exist, corresponding to various penetrating powers, areas of windows, and distances. They may look bewildering at first sight, and even with these tables it is not possible to know quite accurately the dose which each particular c.cm. in the abdomen or chest will receive, but they are undoubtedly a help to obtain a better understanding of the distribution of the intensities in various regions and as the success or failure of the treatment of deep-seated malignant diseases depends to a large extent on the correct distribution of the necessary intensities over the diseased volume, it may be worth while to study them.

It has been proved since that some mistake must have been made when these tables were compiled. There was either too great a distance between the diaphragm and the phantom—the diaphragm should nearly touch the phantom—or else the material used for the diaphragm was not absolutely opaque to the rays used. At any rate, the influence of the scattered rays outside the cone which is exposed

to the influence of the direct rays, appears exaggerated, and is not as great as shown in these diagrams. Later measurements have proved that the intensity of the rays is fairly evenly distributed over a conical surface which has its centre in the focus of the anticathode. It is likely that charts with correct diagrams will be available shortly.

The even distribution of the intensity over a great depth depends also on

The Distance between Anticathode and Skin.—The greater this distance, the better will be the percentage depth dose and the smaller will be the difference in the intensities existing at various depths below the skin (see Figs. on page 128. In Fig. 1 the distance between anticathode and skin is 25 cm., and when the intensity on the skin is equal to 100 units, the intensities prevailing at 4, 6, 8, 10 cm. below the skin will be respectively 74, 65, 57, 51 units, so that at a depth of 10 cm. below

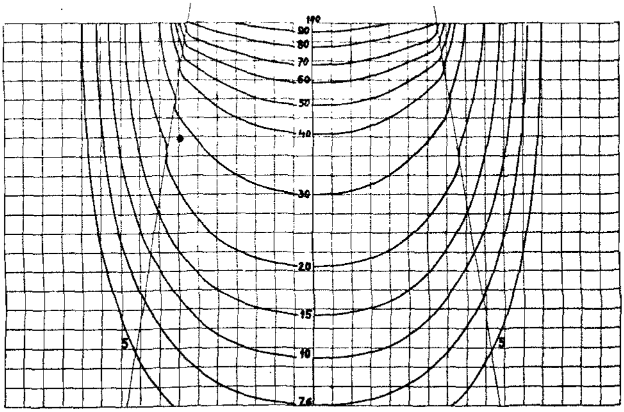


Fig. 49.

the skin, 49 per cent of the surface intensity dose has disappeared owing to the greater distance from the anticathode. If the distance between anticathode and skin were 50 cm., as shown in Fig. 2 on page 128, the intensities at 4, 6, 8, 10 cm. below the skin would be 86, 80, 74, 69 units respectively, so that only 31 per cent is lost at 10 cm. below the surface, owing to the greater distance. For the even distribution between a depth of, say, 6 to 12 cm., it would therefore be an advantage always to use large distances, but the duration of the exposures will increase rapidly, because four times as large a quantity of X rays will have to be produced with a distance of 50 cm. to secure a certain effect, as with a distance of 25 cm. only. The inconvenience to the patient, the loss of time to the operator, and the expense of the treatment,

would be increased very much, and a compromise has therefore to be made in this respect. When organs 7 to 10 cm. below the skin have to be treated, a distance of 23 cm. between anticathode and skin is at present considered best.

If the diseased organ is no more than 1 to 5 cm. below the skin, as in cases of mammary cancer, etc., distances as great as 60 or even 100 cm. may have to be used to obtain doses of fairly similar intensity at 1 or 3 cm. below the skin. The cross-fire method is not possible for such cases, because the different windows would have to be placed so close together that they would be bound to overlap on the skin, or at any rate immediately below it.

If the distance between anticathode and skin were 23 cm., only about 50 per cent of the surface dose would penetrate to a depth of 4 or 5 cm. If the exposure were continued till the erythema dose had been obtained at this depth, the skin would have received about 200 per cent of the erythema dose, and a severe and painful ulcer would be the result. If the exposure were stopped when the surface had received an erythema dose, malignant cells 3 to 4 cm. below the skin would not have received even the dose which paralyses them. They would only have been irritated. This may account for some of the failures which have been reported in the treatment of carcinomas of the mammæ, the vulva, the stomach, etc.

The difficulty can be overcome if a greater distance is used between the anticathode and skin, and a larger aperture is chosen for the window. If the distance is increased to 80 cm. and the size of the window to 15 × 12 cm., the percentage of the surface dose which will penetrate to a depth of 3 cm. below the surface will increase to 90, and carcinoma cells situated at such a depth can be exposed to the lethal dose without risking any serious injury to the skin.

The distance which it is best to use with such cases depends on the thickness of the infected parts, and may vary from 50 up to 100 cm. The duration of the exposure has to be increased accordingly, and may vary from 3 to 10 hours for the full carcinoma dose. If the erythema dose can be obtained with a particular tube in 25 minutes at a distance of 23 cm., the time required with a distance of 80 cm. would be

$$\frac{25 \times 80^2}{23^2} = 302 \text{ minutes, or 5 hours, 2 minutes.}$$

As the depth dose increases also with the larger size of the window, it is necessary to consult the exposure tables given with the spectrometer (see page 135) or to make some experiments on the phantom, as described on pages 55 and 56. Exposures of such length are a great inconvenience and expense. They can be reduced if an

Auxiliary Filter, consisting of a block of paraffin wax 10 cm. thick, is placed above the skin. The effect of this is twofold. In the first place the drop in intensity of the X rays per centimetre of depth grows less as they penetrate further into the body. A reference to table No. 8, on page 128,

will show this at once. The difference in intensity between the skin and 3 cm. depth is greater than that between the 9th and the 12th cm. The super-position of a 10 cm. block of wax has the effect of moving the skin to a point 10 cm. deep in the body, and a point 3 cm. under the skin is then more nearly at the same intensity as the skin.

The second effect is to bunch scattered rays from the wax block into the body as shown in Fig. 50, thus increasing the intensity of the available rays.

Thus, with a distance of 23 cm. between anticathode and skin, the latter, under the wax block, will receive only 20 per cent of an erythema dose in 30 minutes, and in the same time the point 3 cm. below the skin receives 17 per cent. If the exposure is continued for 2½ hours the skin will have received a full erythema dose and the point 3 cm. under it will have had 85 per cent, which is very near the carcinoma dose. Thus the relationship between the skin intensity and that at 3 cm. depth is as good when the auxiliary filter at 23 cm. anticathode skin distance is used as it would be at an 80 cm. distance without the filter, but the time which is necessary for the exposure with the filter at 23 cm. is only about one-third of that required at 80 cm. distance.

Finding Empirically the Duration of Exposure for producing an Erythema.—With unfiltered rays, of medium penetrating power, equivalent sparks about 12 to 15 cm., a current of 2·5 M.A. in the tube, and a distance of 25 cm. between anticathode and skin, an erythema can be produced in some 6 to 8 minutes. Under similar conditions, but with a tube with an equivalent spark of 30 cm., it may take 12 minutes, because a smaller quantity of these harder rays is absorbed. With an aluminium filter 3 mm. thick, it may take 15 to 25 minutes. With a zinc filter 0·5 mm. thick, and tubes with an equivalent spark of 40 cm., and an electrical apparatus specially constructed for these purposes, the erythema dose may be obtained now in 18 to 36 minutes. with a focus skin distance of 23 cm. The exact time varies with the apparatus, tube, voltage and number of M.A., and distance used.

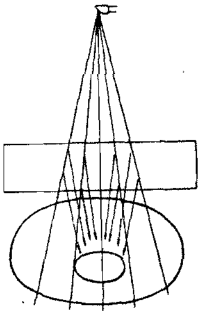


Fig. 50.

The manufacturers of the apparatus can give some information about the approximate time required, but the operator should carry out some experiments both to ascertain the time necessary for the erythema dose and to become familiar with the apparatus, before any exposures are made on the patients. This can be done in various ways. For instance, it is known that with rays from a tube with an equivalent spark of 30 cm., which have been filtered through 0·5 mm. zinc or copper, between

dose is produced on a skin which is exposed at double the distance existing between focus and Sabouraud pastille.

If the focus *filter* distance is 15 cm. and a Sabouraud pastille exposed just below the filter (it should be exposed in a small ebonite cup which can be attached to the central part of the filter with wax) shows Teinte B after an exposure lasting 15 minutes, this would mean that with a focus *skin* distance of 30 cm., the full erythema dose would at any rate require more than three times 15, i.e., 45 minutes, and it would be safe to give an exposure of this duration without fear of exceeding the erythema dose. If 45 minutes can be given with a focus skin distance of 30 c.m., we can calculate the time for which it is safe to expose at, say 23 cm., by applying the inverse square law. It is $45 \times \frac{23^2}{30^2} = 26{\cdot}5$ minutes, or, at 20 cm., it would be $45 \times \frac{20^2}{30^2} = 20$ minutes (see tables 5 and 6 on page 127).

When the approximate time has been found out experimentally in this way, exposures should be made on an arm or leg or, since the ovaries are more sensitive than other organs, it is convenient to use patients whose ovaries have to be sterilized on account of profuse hæmorrhage, to find the duration of the exposure required to produce an erythema with an individual tube, as these cases allow a greater latitude in the exposure than most others. The dose may be exceeded by as much as 150 per cent before other organs are injured, and if the dose has been too small, the patient can be exposed once more four weeks afterwards, without danger that the time lost may have such serious consequences as would be the case with a patient suffering from malignant diseases.

A tube with an equivalent spark of about 40 cm., a zinc filter 0·5 mm. thick, a diaphragm with an aperture of 6×8 cm., and a distance of 23 cm. between anticathode and skin should be used. Supposing that with this particular tube it should be possible to obtain an erythema in 24 minutes, and that the spectrometer or a test on the phantom has shown that at a depth of 8 cm. 25 per cent of the surface dose can be obtained with it, an ovary situated at such a depth would receive 50 per cent of an erythema dose if a total exposure of 48 minutes were given. As this would injure the skin, it is divided over two windows and 24 minutes' exposure is given to each. If it should turn out afterwards that the 24 minutes' exposure did not produce an erythema, and that even 35 minutes are necessary to obtain this with the tube and under the conditions used, the two windows together would have received with the 48 minutes' exposure a total of $\frac{48 \times 100}{35} = 137$ per cent, and the ovaries $\frac{25 \times 137}{100} = 34$ per cent of an erythema dose. This is sufficient to produce the desired sterilization.

The appearance of the skin will most likely give some indication whether an erythema would have been reached if the exposure had been continued five minutes longer. To find this out by actual experiment we can make

other trial exposures. We can use on another patient 34 minutes for o window on the abdomen, but as there is no need that the ovaries shou receive a larger dose than in the experiment mentioned above, it is r desirable to make the total exposure for one ovary longer than 60 minut and so the second window on the back need be exposed for 26 minu only.

In this way we can find out empirically how many minutes the exposu has to last to produce an erythema, without much trouble and without ri to the patient or failure in the treatment. The one tube which has th been tested should be kept as a standard for comparison. How other tul can be compared with it has been explained already on page 51.

How Long have the Exposures to last?—When it is known in what ti an erythema can be produced with a given tube, and what percentage of t surface dose will penetrate to various depths, the duration of the exposu required to produce certain percentages of the erythema dose at varic depths can be found out by simple calculations.

For instance, if 28 minutes' exposure should be required to produ an erythema, and if 26 per cent of the surface dose penetrates to a depth 8 cm., the total exposure required to obtain 34 per cent of the erythema d at a depth of 8 cm. will be $\frac{28 \times 34}{26} = 36{\cdot}6$ minutes. This would be t much for one window, but with two exposures of 18 minutes' durati each, given through two windows, the dose necessary for sterilization an ovary can be obtained under the conditions mentioned above, withc injury to the skin; 72 minutes' total exposure, divided over four windo would be sufficient to produce the sterilization of both ovaries of a patic of normal size. For stout patients about 10 minutes more should be giv If one large window is used at the back, instead of two small ones, the t can be reduced a little further.

If we wish to apply to a carcinoma 10 cm. below the surface a dose 105 per cent of the erythema dose, and if 20 per cent of the surface d penetrates to this depth, we have to expose under the conditions mentior above $\frac{24 \times 105}{20} = 126$ minutes. In order not to exceed the 28 minu for one window, six windows will have to be used, with 21 minut exposure through each. Stout patients should receive about 3 minu more through each window, thin patients about 2 or 3 minu less.

If, instead of this, 26 minutes were given through each window, 131 cent of the erythema dose would reach the region of the uterus, and thi too near the dose which causes injuries to the bowels. If we were to exp 16 minutes only, we should obtain 84 per cent of the erythema dose only the depth of 10 cm., which is a little below the minimum which has been fo to be necessary.

Strength of Current to be used.—With gas tubes, 2·2 to 2·5 M.A. are usually employed for these exposures; with Coolidge tubes, 3 M.A. With most electrical apparatus it is possible to produce stronger currents, and the duration of the exposures could be reduced to one half if 5 M.A. were used instead of only 2·5, but this is not yet practical for exposures of long duration with these high voltages, partly because the risk of injury to the tubes and electrical apparatus becomes too great if currents of 4 M.A. and more are maintained for any length of time, but chiefly because it has been found by experiment that the percentage of the depth dose begins to grow gradually smaller when currents of about 2·5 M.A. are exceeded.

The Sterilization of the Ovaries.—From the results obtained in thousands of cases, it was known that the ovaries were much more sensitive to X rays than the skin, but it was not known whether 60 or 40 or 20 per cent of the dose producing an erythema would cause atrophy of the ovaries. In the clinics of Freiburg and Erlangen the dose which reached the ovaries was measured carefully, partly by introducing the ionizing chamber of the Ionto quantimeter into the vagina, and partly by using tubes which had been tested carefully.

At first they timed the exposures so that 50 per cent of the erythema dose reached the ovaries. With all patients treated with such a dose, the menses ceased. The dose was then reduced gradually, and they found that when the ovaries had received 34 per cent of the erythema dose the menses ceased invariably, but when the exposure was still further reduced, till the ovaries had received only 28 per cent of the erythema dose, the results were uncertain. With some patients the sterilization was then only temporary and the menses reappeared after eight to fifteen months; with others it was not produced at all.

They found also that it makes a difference whether the X-ray treatment is applied in one sitting during the fortnight immediately succeeding or immediately preceding a period. In the first case—

95·0 per cent of all patients did not have another menstruation;
5·0 per cent had one more menstruation.

When the X rays were applied in one sitting during the fortnight preceding a period—

3·8 per cent had no further period;
79·7 per cent had one more menstruation;
14·0 per cent had two more; and
2·5 had three more menstruations.

If the dose was applied in several sittings during the first fortnight after a period—

14·5 per cent had no further menstruation;
83·0 per cent had one more; and
2·5 per cent had two more periods.

If the dose was applied in several sittings during the fortnight preceding a period—

0·0 per cent had no further period ;
7·8 per cent had one more ;
82·4 per cent had two more ; and
9·8 per cent had three more periods.

These experiences prove that the biological effect of a certain dose varies according to the time which elapses after a period, before the exposure is made, and that the same dose has a different effect when applied on one day or when it is spread over several days. It is greatest if the whole dose is given on one day, but the effect decreases when intermittent applications are given. The longer the intervals, the smaller will be the effect.

It is important to remember these things, because if a patient who was treated during the fortnight preceding a period has one or two or even three more periods after the X rays were applied, this is not yet a proof that the treatment was not successful. A definite opinion can only be formed after the third period.

It does happen that if unusually sensitive or nervous patients decline to have the whole dose applied on one day the treatment has to be spread over two consecutive days, one ovary being sterilized on one day, and the second a day or two later ; but the total dose has then to be increased by 20 per cent.

If the ovaries are exposed to 30 per cent of the erythema dose, all the follicles are usually killed, but the functions of the interstitial glands remain unimpaired. If the dose is reduced so far that only 27 per cent of the erythema dose reaches the ovaries, the sterilization is only temporary, and the menses return after some time, occasionally as late as eighteen months afterwards.

The age of the patients makes no difference ; the ovaries of a woman of 40, who is near the climacterium, require just as large a dose to become atrophied as the ovaries of a young woman of 20. For other reasons, the surgical removal of the uterus is preferred as a rule to the X-ray treatment in cases of women who are below 40 years of age.

Mode of Application.—The bowels and bladder of the patients should be empty. The patient is placed on a table, on which blankets have been spread. This is preferable to a soft mattress, because with the latter the position of the patient may shift and the direction of the cone of rays be so altered thereby that the ovary is no longer in the centre of the cone, or may not be reached at all. It is also more difficult to maintain an even degree of compression.

If at all possible, the exact position of the ovaries should be found out by bimanual examination. If fibroids or tumours are present, this is frequently impossible. A larger window, of about 9 × 9 cm., has then to be used, to make sure that the ovary is reached by the X rays, and the distance between

anticathode and skin may have to be increased to 30 cm. in such cases.

If there is little or no doubt about the position of the ovaries, the distance between anticathode and skin of 23 cm., and a window of 6 × 8 cm. are used. The tube stand, with the wooden diaphragm below the box enclosing the tube, is brought into such a position that an ovary is in the centre of the window, so that the central ray from the tube passes through the ovary. The tube box is then lowered, to press the disc of wood closing the lower end of the frame into the abdomen as far as the patient will allow. Before starting the apparatus, make sure that the zinc filter is in position. The exposure is then made. The position of the tube stand is then altered so that the second ovary is brought under the centre of the tube. After the two exposures have been made on the abdomen, the patient has to turn round and lie face downwards so that two more exposures can be made from the back. The window is adjusted on the right and left side of the sacro-iliac joint. It is also possible to use one window only on the back, but in this case it must have a larger size, about 8 × 10, or 9 × 9 cm., and must be placed across the sacrum, and a distance of 30 cm. has to be used.

If the total exposure is to be spread over two days, one ovary has to receive the full dose on one day, i.e., one exposure has to be given through the abdomen and the second through the back, whilst the second ovary is treated on the following or third day; but matters must not be so arranged that each ovary receives half a dose on one day and the other half a day or two later.

Results Obtained.—A large number of patients have been treated for profuse hæmorrhage due to fibroid tumours, or myomas. In the earlier years, an operation was considered preferable or necessary if the growths caused trouble by pressure on the bowels, or the bladder, or arteries, or if a discharge had set in in consequence of necrosis, etc. A great change has taken place in this respect since heavier filters and a greater quantity of very hard rays are available. It has been proved beyond doubt that the tumours shrink after sterilization. Occasionally the process is slow, but in 32 per cent of all cases no trace of a growth can be found any more after twelve months, 60 per cent become very much smaller, and only in 8 per cent of the cases no change is noticeable on examination with the fingers. Retention of urine disappears within two to four days, before any diminution in the size of the tumours is noticeable, and in cases of necrosis great quantities of pus, etc., are frequently discharged soon after an exposure; the myomas begin to shrink and the fever and discharge cease entirely in a short time.

Even tumours of large size are not a contra-indication any more. In 1914 it was still thought necessary to operate on about 20 per cent of all cases of fibroid tumours; but with the improved technique and greater experience, this figure decreased gradually, and only 8 to 10 per cent of all cases are now operated in Erlangen, and a still smaller number in Freiburg. The remaining 90 to 95 per cent are treated with X rays. The former clinic reports that

when in 1916-17 they treated 170 patients for fibroid tumours with X rays with the new method, there was not one single total failure or accident or injury, and they claim therefore 100 per cent cures. In one case, while the patient was lying on her face, a large quantity of blood seems to have discharged into the tumour. She complained of severe pains, and a collapse followed after twelve hours, but the patient recovered gradually within four weeks, and has been in good health since.

76 per cent were successful after one single application.

24 per cent had to be exposed a second time.

The surgical removal of the uterus is considered preferable :—

1. If the patient is considerably below 40 years of age.

2. If the diagnosis is uncertain.

3. If complications like hernia, prolapsus, chronic peritonitis, perforation of the bowels, etc., are present, which make an operation necessary.

4. If pedunculated polypoid fibromata are present.

5. If there is a suspicion that a carcinoma may be present in a tumour of very large size, because it is difficult then to apply a dose of sufficient strength. If the growth is moderate in size, or if a sarcoma is present, X-ray treatment offers decidedly better prospects than a surgical operation.

Over 500 patients were sterilized between 1917 and 1920. With the exception of the one case mentioned above, there was no mishap and the treatment was successful in all cases.

With such results it is not surprising that patients prefer the X-ray treatment infinitely to a surgical removal of the uterus. Though the mortality with the operation may be below 5 per cent, there is *some* risk, and nobody likes the idea of having the abdomen cut open. During the first forty-eight hours after the operation the pains, discomfort, etc., are infinitely greater than after X-ray treatment, and the X-ray sickness is usually only slight after the doses required for sterilization. After an operation a patient has to spend two to four weeks in bed, and it takes two to six months before she recovers her full strength and vitality, whereas after sterilization by X rays the patients can resume their usual daily life and obligations after twenty-four, or at the most forty-eight, hours. Many walk home after the exposure.

The troubles arising after the climacterium—hot flushes, obesity, etc.—are *not* greater in the case of X-ray treatment than after the natural advent of the menopause, and smaller than after a surgical removal of the ovaries.

Considering the ease and certainty with which amenorrhœa can be produced with X-ray treatment, there can be no doubt that in no distant time the number of cases treated with X rays will be much increased, and the number of cases where a surgical operation is preferable will be reduced.

Malignant Tumours.—The excellent results obtained with X-ray treatment in a large number of diseases of the skin, and in the treatment of

excessive hæmorrhage due to myomas or the approaching climacterium, are admitted generally. But opinions differ as yet on the questions as to whether and to what extent X rays are preferable to a surgical operation in the case of deep-seated malignant diseases, or whether both should be used in combination.

As far as I am aware, Professors Seitz and Wintz have obtained better results with their method of treating deep-seated malignant diseases with X rays than have been recorded elsewhere. The introduction to the chapter describing the X-ray treatment of malignant tumours in their book, " Unsere Methode der Röntgen Tiefen Therapie und ihre Erfolge," may be summarized as follows :—

" It is fairly easy to produce sterilization of the ovaries, because they are so very sensitive to X rays, and because it is not very difficult to find their position. Malignant tumours offer much greater difficulties, partly because they are less sensitive to X rays, and partly because it is impossible to say how far malignant cells may have already invaded the healthy tissues in the neighbourhood. It does happen that glands in the neighbourhood of a malignant tumour are infected very soon after it has begun to appear. For this reason the surgeons remove larger and larger parts of the surrounding tissues, but their knife has to stop short of many important organs, which must be left intact, whereas the X rays can traverse them with impunity as long as a certain dose is not exceeded. They can do their work more efficiently, and over a larger area, than the knife of the surgeon. This is the great advantage which gives rise to the hope that in certain cases better results will be obtained with X rays than with surgical operations.

" If metastases have already been started far away, X rays are powerless, because it is impossible to treat the greater part of the body with a dose of sufficient intensity to destroy malignant cells without injuring the blood, etc., too much. The patients can stand only a moderate dose of the X-ray toxin. For malignant diseases the prospects of a permanent cure are better if no surgical operation has yet been performed. A patient suffering from a sarcoma has better prospects of a permanent cure with X rays than a patient suffering from a carcinoma. It is too early as yet to form a definite judgment about the value of the X rays in combating malignant diseases, as the experiences are too short, but the results which have been obtained so far compare favourably with the results of surgical operations. This is especially the case with malignant diseases of the uterus. Although the X-ray treatment of these cases is still in its infancy, the prospects of a cure are already somewhat greater, when the treatment is carefully carried out, than when a surgical operation is performed.

" The results obtained with carcinomas of the ovaries, the rectum, stomach, œsophagus, the mammæ, the larynx, etc., up to now have been not nearly as good as those with the uterus, but it is to be hoped that with improved technique better results will be obtained in these cases too.

Temporary improvement and alleviation of pain have been reached in most cases."

Comparison of the Results obtained with X Rays and with Radium.—When the treatment of malignant tumours of the uterus was begun systematically with X rays in 1914, it was known that radium would make a malignant tumour disappear within a radius of about 35 mm. from the tube. Under these circumstances it was not considered fair to the patients to give up radium treatment, and for several years a combined X-ray and radium therapy was employed. Of the latter, 100 to 150 mgrm. were used in a brass tube with walls 1 mm. thick. Over this an indiarubber tube was slipped, and it was introduced into the cervix for twenty-four hours.

In the first years only those cases which were considered to be already past surgical help were treated with X rays and radium, and some of the results will be found below.

As the number of cures with a surgical operation increases when the surgeons do not remove the tumour only, but also a large quantity of the adjoining tissues, radium was soon considered unsatisfactory, because the intensity of the radium rays diminishes as the square of the distance increases. If the intensity at a distance of 10 mm. from the tube is 1, it will be reduced at 40 mm. distance to 0·063, and this is equal to only 5 per cent of the initial energy. If the radium were allowed to act till tissues 30 to 40 mm. away from the tube had received 110 per cent of the erythema dose, all the tissues which are only 5 to 10 mm. away would have received more than 100 times this dose, and severe ulcers would be the result. Tissues at a distance beyond 40 mm. would not receive enough. With 100 mgrm. of radium, the carcinoma dose can be produced at a distance of 20 mm. in 17½ hours, at 30 mm. in 32 hours. Since 1915 a few cases have been treated with X rays only, and since 1918 radium has been given up altogether. In a report made in 1922, Professor Seitz states, that of 67 cases of carcinomas of the cervix which were treated with radium and X rays combined, 56 per cent—and of 34 cases which were treated with X rays only, 53 per cent—were alive and well, and free from reactions, two years after the treatment.

If radium were available in sufficiently large quantities, so that it could be employed at distances of from 20 to 50 cm., it would be more convenient than the X rays, but with the minute quantities at our disposal the intensities become so very small, at such distances, that the exposures would have to be extended over weeks. In this respect the X rays have a great advantage over radium, because they can be produced in such large quantities that distances as great as 50 or even 100 cm. may be used.

Dr. Béclère declares that *all* the results which can be obtained with radium can be obtained with X rays too, but not vice versa, and that the numerous patients who cannot obtain treatment with radium, owing to its scarcity and price, have no reason to bewail this fact.

The Duration of the Exposure for Carcinomas of the Uterus.—The margin is much smaller than with the sterilization dose. A comparatively slight

under-exposure means failure of the treatment, and over-exposure, injury to the bowels.

If the constants of the tube and apparatus used are as mentioned on page 94, patients of normal size should be given an exposure of 16 to 18 minutes for each of the six windows, stout patients a few minutes more, thin patients a few minutes less.

Mode of Application.—Instead of applying X rays to the uterus only, three series of exposures are given now with an interval of six to eight weeks between them. The first is directed towards the tumour itself, the area covered at 10 cm. depth measures 9 × 12 cm. when the windows are 6 × 8 cm. wide, and the distance between anticathode and skin 23 cm. Six weeks after the first exposures a second series is given, and the cones are directed so that the 9 × 12 cm. adjoining on the right side of the uterus are covered. Six to eight weeks after this, the third application is given, to expose the region on the left side of the uterus. If the disease were confined to the uterus alone, the two additional exposures would not be necessary, but as it is quite likely that organs in the neighbourhood have already been infected, the other exposures are given to reach these possible extensions too. The total area exposed then measures about 30 cm. across the abdomen and 22 lengthwise.

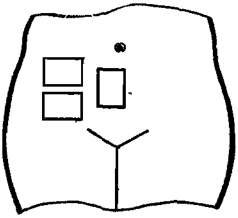


Fig. 51.

For the second and third application, six windows are used too; two of them on the abdomen and on the back are so adjusted that the centres of the windows are about 10 cm. from the middle line, the third window on the abdomen and back is above the middle line, but the tube box is inclined so that the cone of the rays points towards the right side of the patient with the second, and towards the left side with the third application. The right side is chosen first, because the rectum is somewhat to the left, and if it can be arranged it is desirable to allow this organ as long an interval of rest as possible between two exposures.

Results.—The discharge from a malignant tumour which has been subjected to a dose of X rays as described above, becomes gradually smaller, or ceases entirely within the first fortnight. After that time the tumours begin to shrink slowly, and after six to nine weeks they have disappeared. On examination with the microscope, the malignant cells appear first hyperæmic and enlarged, and cannot be stained as readily, but the chief feature is the gradual appearance of a large number of small cells. About three weeks after the exposure the malignant cells begin to shrink, and after about twelve weeks they have usually disappeared entirely.

When sarcomas have been exposed to 60 or 70 per cent of the erythema

dose, they shrink fairly quickly ; some disappear entirely within a few days. The majority have disappeared within four to six weeks. This rapid change causes severe toxic symptoms, but even patients who are already in a low condition recover comparatively easily.

In cases in which it is not quite certain whether a tumour of the uterus is a myoma or a sarcoma, it is safe to continue the exposure till the tumour has been subjected to 70 per cent of the erythema dose. If it is a sarcoma, it will most likely disappear in a few weeks ; if it is a myoma, it will take several months to shrink and disappear. As far as can be judged now, after four years' experience, the prospects of a permanent cure for sarcomas are about three times as great with X-ray treatment as with a surgical operation.

Other Opinions.—The book of Professors Seitz and Wintz was published in 1920. Since that time numerous and detailed reports have appeared about the experiences gained at many other universities and large hospitals, in many thousands of cases and in many countries of the world. The claims made by the clinics at Freiburg and Erlangen about the excellent results obtained with X-ray treatment of excessive hæmorrhage, and the good results with sarcomas, are admitted unanimously. Statistics compiled from *all* cases of sarcomas treated with X rays since 1905, about which reports were published, show that 30 per cent of the sarcomas disappear entirely, 50 per cent shrink, and 20 per cent are not influenced at all by X rays. Good results of the X-ray treatment of carcinomas of the uterus are reported by a majority.

Carcinomas of the Cervix.—In the *Münchener medizin. Wochenschrift*, 1922, page 221, Professor Döderlein, of Munich, publishes an analysis of the statistics of the Gynæcological Clinic of the University of over one thousand cases of carcinoma of the cervix. Out of 265 cases which applied for treatment during the years 1908 to 1912, fifty-four, equal to 20·4 per cent, were well and free from recidives 5 years later. As only 167 were still in an operable condition, the relative number cured by the radical operation was 32 per cent. During the years 1913 to 1916, five hundred cases applied for treatment. All of these were treated exclusively with radiation. Sixty-nine of them, equal to 13·8 per cent, were well and free from recidives 5 years later. At first sight this looks less favourable than the 20·4 per cent cured by the surgical operation, but after it had become known that the patients would be treated by radiation, the number of cases applying for treatment became *five times* as great as before ! But the number of cases past surgical help increased so much, that the number of *operable* cases dropped from 63 per cent of the admitted cases to 33·9 per cent, i.e., just about one half of the former years. It is therefore only reasonable that the percentage of the admitted cases who could hope for a cure has to be reduced to one half too, i.e., from 20·4 to 10·2 per cent, and the 13·8 per cent which were actually cured by radiation therefore compare favourably

Professor Döderlein divides the cases in four classes :—

The first class contained 77 cases which were still operable. Thirty-seven of these, equal to 48 per cent, were well and free from recidives 5 to 8 years after the treatment.

The second class contained 90 cases, in which it was doubtful whether an operation was still possible. A trial laparotomy might have decided. Of this class 18 patients, equal to 20 per cent, were cured.

The third class contained 214 cases which were past surgical help. Radiation was applied in spite of the fact that the carcinoma had already invaded distant organs. Thirteen patients only, equal to 6·07 per cent, were cured.

The fourth class contained 119 quite desolate cases ; one only of these was cured.

The 32 cures out of classes 2 to 4 are undoubtedly a clear gain compared with operations. But it is unsatisfactory that only 48 per cent of the first group were cured. This is, however, not due to the method, but to the fact that a considerable number of the patients did not return for the second exposure, in spite of the instructions given. Of 43 patients of the first class who came back for a second exposure at the appointed time, 35, equal to 81 per cent, were cured. Of the 50 of the second class on whom the treatment could be finished, 18, equal to 36 per cent, and of the 121 of the third class, 13, equal to 10·4 per cent, were cured.

In concluding, Professor Döderlein states that the prospects of a cure with surgical operation as well as with radiation depend to a very large extent on the early recognition of the disease, and commencement of the treatment. Irregularities in the menstruation, loss of blood post coitum, suspicious discharge after examination with a finger or speculum, bleeding erosions, etc., call for careful expert examination.

This report has attracted great attention, because it allows a comparison of the prospects of success with surgical operation and with radiation in cases of carcinomas of the uterus. Although three other gynæcological clinics have followed Professor Döderlein's example, and have abandoned operations for carcinomas of the uterus, most others prefer to operate, and to hand only the hopeless cases to the X-ray department. This obviously does not allow a fair comparison. But even of those cases of carcinomas of the uterus, which were considered hopeless by the surgeons, some have become operable after X-ray treatment, and some have been cured. The number of the latter is given as low as 6 per cent only by one hospital, another report from a large hospital claims 14 per cent, and Professor Döderlein shows still better results. If *all* the patients could be induced to come back for the second exposure at the appointed time, the above figures could be nearly doubled.

Moreover, one large hospital reports, after an analysis of 200 cases of carcinomas of the uterus, of which *all* were operated, and about 40 per cent were treated after the operation with X rays as a prophylactic measure, that of the latter cases nearly twice as many were well and free from recidives 5 years after the treatment, as of those cases which were operated only. In

another report it is stated that of 126 cases which were operated only, 45, and of 64 cases which were operated and treated in addition with X rays, 46 cases were well and free from recidives 5 years later.

Carcinomas of the uterus, however, occupy an exceptional position. On the one hand, the number of permanent cures obtained with the radical surgical operation is low, compared with the results obtained with operations on carcinomas of many other organs, and the primary mortality is fairly high. On the other hand, X-ray treatment gives very much better results with carcinomas of the uterus than with those of any other internal organs, with the only exception of carcinomas of the thyroid gland.

Carcinomas of Other Organs.—Only a few permanent cures are reported of carcinomas of the rectum, stomach, and œsophagus. Carcinomas of the tongue and the pharynx have not yet been cured with X rays (a very few cases of carcinoma of the tongue have been cured with radium), and some cases of carcinomas of the larynx have even been made worse with the X-ray treatment.

There is a great difference in the sensibility of different carcinomas: Cancroids of the skin of the face can be cured with comparative certainty with X rays, whereas cancer of the tongue close by proves refractory.

Professor Perthes (who was the first to recognize the great advantage and importance of filters, and recommended their use as early as 1902) sent a circular letter to the *surgical* clinics of 26 universities, with a number of questions, and received replies from all of them.

The first question was: Do you prefer occasionally to treat operable cases of carcinomas with X rays, instead of operating them? Fifteen replied with no, 2 use X rays when the operation is refused, 7 occasionally treat carcinomas on the skin of the face of old people with X rays.

The second question was: Can the results of surgical operations of carcinomas be improved by combination with X-ray treatment? Do you especially expose the mammæ to X rays after operation? Thirteen answered yes, 13 no. Professor Bier has the impression that recidives of the carcinoma of the mammæ are less frequent after prophylactic X-ray treatment, others hold the opposite opinion. It was a surprise to find, that those clinics which used comparatively weak doses for prophylactic exposures had seen the best results. The number of recidives increased when strong doses, the so-called carcinoma doses, were applied after the operation. When large volumes of the body are exposed to strong doses, the blood is injured, and this may be the explanation for the observation that after the operation of the mammæ, prophylactic exposures with strong doses increase the tendency to recidives, instead of diminishing them.

Inoperable cases of the mammæ have not yet been cured permanently with X rays, but in many cases a temporary improvement and relief of pain, etc., lasting occasionally as long as 3, 4 or even 5 years, have been obtained.

In spite of these failures, the use of X rays is steadily increasing in the

treatment of malignant diseases. This is due to the following facts: It is generally admitted that they are a powerful weapon in fighting malignant diseases. They have undoubtedly proved very useful in many malignant skin diseases, in the treatment of sarcomas, and in carcinomas of the uterus. Of carcinomas of other organs, a certain number of inoperable and hopeless cases have become operable or have been cured, and in the large majority of those cases whose ultimate fate could not be averted by X rays, pain has been relieved, and the progress of the malady considerably retarded, frequently by twelve or even eighteen months.

Many more details than I could give about this matter will be found in an article, which appeared in the *Lancet* of 1923, pages 373–8, on "The Clinical Results of the Treatment of Malignant Diseases," by J. H. Douglas Webster, M.D., Physician in Charge of the Radiological Department of the Middlesex Hospital, London.

About minor details the opinions differ a good deal as yet. It is, for instance, disputed by many that a dose which can be called "carcinoma dose" exists at all, because in many cases the 100 per cent of the erythema dose was not sufficient to make a tumour disappear. The sensibility of carcinomas towards X rays differs a good deal; it varies largely with the organs of the body on which they appear. A carcinoma of the uterus offers much better prospects of a cure than one of the ovaries, or the rectum close by. Much depends on the general state of health. Carcinomas discovered in the early stage, or appearing in young patients, react much better than those discovered late, or appearing in old patients. The malignancy varies also with patients living in towns or in the country, and even as between one district and another. The 100 per cent of the erythema dose is considered therefore by many to mean only the "*minimum dose* for carcinomas," which may have to be increased according to individual conditions. The experience that carcinoma cells show no tendency to shrink before they have been reached by about 100 per cent of the erythema dose seems to be general.

Three years after his book has been published, Professor Wintz declared in a lecture, that he does not mean the "carcinoma dose" to be a dose which will restore the patient to health, but merely a dose which will injure the carcinoma cells. It depends, then, on the condition of the patient's body whether he will be able to eliminate the injured cells or not.

There seem to be well-founded doubts, too, whether all carcinoma cell can ever be killed by X rays. Live and intact cells are found occasionally i the discharges from tumours which begin to shrink after exposure to X rays It has even been suggested by some that the general health is improved i consequence, so that the surrounding normal tissues can get the better o the malignant cells. The healthy cells in the neighbourhood undoubtedly show greater activity. Some attribute this to stimulation by the X rays others think that it is due to the fact that the normal cells find mor room after the disappearance of the malignant cells, or explain it merely by the irritation produced by the necrotic discharges from the shrinking tumour

Should the Total Dose be given on One Day or in intermittent applications?—About this question opinions are divided. If the dose given in one sitting is large enough to produce the desired biological effect, a smaller *total* quantity has to be administered than when the dose is divided over many exposures, with several days' or even weeks' interval between each. The organs have the tendency to recover, until they have been subjected to a lethal dose. As the degree of recovery is not known—it varies with the susceptibility of the various organs to X rays, and with the intensity of the dose given at each exposure, and with the length of time elapsing between two exposures—a larger total quantity has to be given; the single dose is more accurate, and it is a saving in time and money. It is therefore recommended by the Erlangen school, but others maintain that the skin, blood, and other organs recover too, and at a quicker rate, because they are less susceptible and have therefore been injured to a smaller extent, and experience shows that, for instance, sterilization can be produced with a large number of very weak doses. In a report made before a medical society in Paris, Dr. Béclère stated that he had treated successfully some 300 cases of profuse hæmorrhage, with exposures of only five minutes' duration each, but continued over several months, until the hæmorrhage ceased. In the majority of these cases sterilization occurred after total exposures of between two and three hours had been given. This means an average of 25 separate exposures of five minutes each for each case.

The advantage of these very small doses is that no trace of X-ray sickness was ever noticed, but it is surely a great waste of time and money, which many patients cannot afford, and which would be dangerous with malignant diseases. Much stronger doses can certainly be given at one sitting without inconvenience worth speaking of. These very weak doses have been given up by the great majority; but, on the other hand, the opposition of those who consider it a mistake to go to the other extreme and give the whole dose, especially the very large doses required for the treatment of deep-seated carcinomas, on one day, is steadily growing, on account of the X-ray sickness. It seems that the sterilization dose can be borne by the majority of patients without X-ray sickness, but the number of those medical men who consider it best that for the first sitting only two windows should be exposed, with about 90 per cent of the erythema dose each, seems to be on the increase. When it is found that the patient can tolerate the X-ray treatment without serious symptoms, the remainder of the dose is applied a few days later.

The X-ray Sickness.—The symptoms of this are: headache, want of appetite, and in more severe cases vomiting and even diarrhœa, occasionally mixed with blood. The severity and duration of the sickness varies a good deal, and depends chiefly on the duration and intensity of the exposure, and on the organs which were exposed.

The extremities, arms and legs, are scarcely susceptible, whereas the abdomen and the chest are very sensitive. Some patients also suffer a good deal more than others. When the sterilization dose is given in one sitting,

many escape with a headache lasting for twelve to twenty-four hours; bu the doses required to treat a deep-seated carcinoma with 100 per cent of th erythema dose in one sitting, seem to have produced in some cases such severe sickness, with diarrhœa lasting for several weeks, that some docto declare it to be dangerous to give more than about 25 per cent of it at th first sitting. They can thus test the individual susceptibility, and the bloo etc., seem to acquire a certain immunity, as subsequent exposures are born somewhat more easily than the first one.

The cause of this sickness is not yet fully explained. It has bee suggested that the ozone and the poisonous gases, which are generated b the sparks and brush discharges, may be the cause; but if it were so, the nurs and other attendants who spend a much longer time in these rooms woul be attacked in the first instance. The quantity of these poisonous gases too small to be responsible for this sickness, but they are no doubt the caus of the great lassitude and drowsiness about which the assistants complai so frequently. It has been mentioned already that the brush discharges ca be reduced very much by using polished brass tubes as conductors, instead o the usual thin wires, and that it is important that the rooms should be we ventilated.

The sickness of the patients seems to be due to some irritant action o the rays on the bowels, the stomach, and the blood, which is likely to becom overloaded with débris of cells which have been killed by the X rays. Beside this, well-marked changes are produced in the blood, which can easily b proved with the microscope. In particular, the number of leucocytes become reduced in proportion to the quantity of X rays which reached the body With the sterilization dose, the blood always recovers its normal compositio so far as this can be proved with the microscope, within three weeks; wit the dose required for carcinomas, six or even eight weeks are required befo this has taken place. The changes in the blood place a limit on the are which may safely be treated with the carcinoma dose at one exposure; othe wise it would be quite possible to expose the whole abdomen to this quantit of rays. After the blood has recovered, a second exposure may be give after eight weeks, and a third one after sixteen weeks. With some patient however, the blood seems to have lost the power to recuperate; the vitalit has been lowered too far already by the malignant disease. With most o these the X-ray treatment proved fruitless, and though the tumours ma have disappeared, they succumbed. With a few, transfusion of the bloo has been carried out successfully; they recovered, and are in goo health.

Dr. Holzknecht, of Vienna, the well-known pioneer of X-ray science reported recently that an injection of 10 c.cm. of a 10 per cent solution of sal into the veins makes the symptoms of the X-ray sickness disappear withi about an hour. He was led to try salt, because the blood of patient suffering from this sickness contains less than the normal quantity of salt His experience has already been confirmed since by several others who hav

Injuries and Accidents.—As many thousand X-ray exposures are made every day, it is not surprising that a large number of injuries have already been caused. The more severe injuries, and some fatal accidents are more or less confined to therapeutic exposures, but slighter injuries are frequent enough even with diagnostic examinations.

Over-exposures which are responsible for most injuries may be due to a variety of causes. Thus, for instance, want of knowledge and experience in determining the correct dose, errors in measuring the quality and quantity of the rays used, or mistakes in measuring the focus skin distance or making correct allowance for any change of it, will all cause an incorrect dose to be applied. More serious faults are the omission to insert the filter, and the omission to switch the current off at the intended time, if, for instance, the operator has more than one patient to attend to, or other duties to carry out, while the exposure is going on. Then again excess dosage will arise by an accidental exposure of the same part of the skin for a second time, or by allowing too short a period of rest after a previous exposure. It is essential that eight weeks should be allowed to any part of the skin which has been exposed to a full erythema dose, and four weeks and two weeks for half or quarter of such a dose respectively. Moreover, a patient who has been exposed a few weeks or months previously to X rays somewhere else, will be unusually sensitive to the rays. The same applies to patients who have inflammation of the skin or who have used ointments or medicines containing mercury, zinc, bismuth, iodine, etc., or who are suffering from diseases such as nephritis, syphilis, diabetes, etc.

Errors in adjusting the direction and position of the tube, so that the cones of rays overlap and that the *same* part of sensitive organs like the bowels are included too frequently in the cone of rays, may cause stenosis or even rupture, and peritonitis may be the result. The bladder, the larynx and brain are also very sensitive to over-exposures. Fluctuations in the supply of the current from the main may also be responsible, though they lead more frequently to an under- than to an over-exposure.

Injuries occasionally appear as late as a year or even several years after the exposure. The vitality of the epidermis or the epithelial cells may have been lowered, and the skin then remains very sensitive to subsequent mechanical injuries, pressure, friction or irritation by chemicals. Irritant soap has repeatedly been traced as the cause of late injuries appearing. One case is recorded in which a surgeon spilled a little hydrochloric acid over his left hand, and an X-ray dermatitis appeared a year afterwards, but was confined to that part of the skin only which had been in contact with the acid for half a minute, the other parts of the skin remained healthy, though they had been exposed to the same small doses of X rays.

The degree of the injuries varies with the degree of over-exposure, and *with the area which has been exposed.* Even a serious over-exposure confined to a small area, will do less harm than a comparatively small over-exposure spread over a large area. A case is reported in which the filter was forgotten,

and an area of about 12 $cm.^2$ received fully five erythema doses, but no ulcer followed. The locality of the over-exposure is also important.

Organs which are normally exposed to great wear and tear, like the feet, the hands, the anus, etc., are very susceptible in this respect. The anus is exposed to pressure, friction, and chemical irritation by the fæces, and the soles of the feet to constant pressure in walking. A case is recorded in which the leg had to be amputated ultimately after the foot had been exposed to X rays of moderate intensity, for eight minutes only, for treatment of an eczema. The hands of numerous X-ray operators are a proof of the severe injuries which may follow exposures to weak but often repeated doses, but it has to be remembered that practically *all* these injuries were caused in the first years, when the toxic effects of the X rays were not yet known, when the hands of the operators were invariably held between tube and screen to determine the quality of the rays, or for demonstrations, and when no protecting boxes round the tubes were known. If such injuries are caused nowadays, it is certainly due to great carelessness.

All sorts of ointments have been tried in vain as remedies, but pain can be reduced, and the process of healing can be favourably influenced by applying warm, moist compressors or diathermy, to stimulate the circulation of the blood over the injured area.

Therapeutic exposures should be made under the supervision of medical men only, and those for the treatment of deep-seated malignant diseases only by those who can devote their whole time and attention to this subject.

There is unfortunately no doubt that carelessness, and want of knowledge, skill, and experience in the application of X rays, have claimed numerous victims already; but the benefits which mankind derive from the X rays are infinitely greater; and the latter will go on increasing, and the number of mistakes and accidents will become smaller, as the methods of measuring the dosages and of applying the X rays correctly become better known.

X RAYS IN THE TREATMENT OF SOME INTERNAL DISEASES.

The results which have been obtained with X rays in the treatment of many skin diseases, in gynæcology, and in some kinds of malignant diseases, have attracted such great interest and attention, that their usefulness in the treatment of some internal diseases has almost been overlooked. The results which have already been obtained in a few diseases are, however, so good, that their application certainly deserves attention.

At first sight, it seems almost incredible that X rays might be of any use, for instance, in the treatment of some forms and stages of tuberculosis, diseases of the blood, bronchial asthma, etc., but as early as 1902 Dr. Senn,

of Chicago, reported, that in two cases of leukæmia he had succeeded i reducing the swelling of the spleen and lymphatic glands, and had restore the composition of the blood to the normal, by exposures to X rays. Soo afterwards followed the news that Dr. Albers Schönberg had discovered tha azoospermy could be produced with them, without leaving any visible effec on the skin, and the influence they have on the secretion of internal glands on the blood, and on the rate of growth of young animals, etc., was confirmed by many investigators.

The effect which they have in some diseases has been discovered b mere accident. The improvement which does take place in a high percentag of suitable cases has since been confirmed by so many prominent medical me in different countries of the world, that it is impossible to deny or ignore it.

The Biological Influences of X rays.—Whether the X rays have a chemical or electrical, or mechanical influence on animal tissues, is not yet fully under stood. One theory is, that electrons which, according to modern ideas, ar circulating in a characteristic number and order round the nuclei of atoms are disturbed by the rays ; that the atoms break up in consequence, an cause chemical influences. X rays are not felt, and weak doses produce n visible effects, but it is known that in cells, which have absorbed a dose o X rays of sufficient intensity, the faculty of the chromosomes and cells t divide and multiply is impaired. They may recover, but when the dos has reached a certain strength the cellular nuclei disappear, and necrosis o the cells follows.

The changes produced vary in wide limits with the susceptibility o various groups of cells, and with the quantity of X rays which have bee absorbed. They do not become noticeable to our senses immediately afte the exposure, but with the microscope or chemical analysis some effects o even weak doses can frequently be observed within half an hour after a exposure. When the skin has been exposed to moderate doses, which wi cause an erythema to appear about a week afterwards, a faint redness an a slight itching or burning sensation are noticed by many patients within thirt minutes after the exposure. The intensity of the injury which will follow i determined already at the time the exposure is finished.

Susceptibility of Different Organs.—The groups of cells most sensitiv to X rays are the lymphatic tissues and glands, the leucocytes, ovaries, testicles the suprarenal, and various other glands with internal secretion, like th thyroid, the thymus, hypophysis, the spleen, etc. Considerably less sensitiv are, the skin, the mucous membranes, the follicles of the hairs, the liver, th kidneys, etc. The cells of the muscles and bones are the least sensitive Doses which are over 100 times as great as those which are lethal already t ova or spermatozoa, will only begin to produce noticeable effects on bones Even in the same group of cells the sensitiveness varies ; the same dose ma prove lethal to many of the cells, whereas others are only paralysed for som time, and recover. It is supposed that those cells are most vulnerable t X rays which are near the stage of division, whereas those at rest are les

Increased Activity or Stimulation, Paralysis and Necrosis.—According to the strength of the dose absorbed by the tissues, and their vulnerability, an increased activity, a temporary or permanent paralysis, atrophy, or necrosis will follow the exposure.

The increased activity due to the irritation caused by weak doses is frequently called "stimulation." It is only temporary, and lasts till the irritation has subsided, and its causes have been repaired. It may be repeated once or twice, but it has to be remembered that for a considerable time after the effects which are noticeable to our senses, or which can be discovered even with the microscope, etc., have passed away, a second exposure has a "cumulative" effect. Whether this time of increased susceptibility lasts only a few days, or some weeks, or even several months, depends on the quantity of X rays which have been absorbed, and on the organs which have been exposed. "Stimulating doses" cannot therefore be repeated as frequently as we would like to do it, because even weak doses repeated too frequently will produce toxic effects. The best proofs for this are the hands of numerous medical men and engineers, who exposed them too frequently in the early years, before these toxic effects of the X rays were sufficiently known.

The boundary line between the weak dose which merely irritates so far that it can be called stimulation, and that which begins to paralyse, seems to be very narrow. It varies with the susceptibility of various organs. It is also impossible to limit the action of the rays to a certain group of cells only, without affecting others, for instance, the lymphatic tissues and the blood, at the same time. Also it seems difficult to decide whether some of the effects are due to "stimulation" or to incipient paralysis of the functions of some cells. For instance, when the spleen or the lymphatic tissues have been exposed to a moderate dose, more leucocytes and lymphocytes are found in the blood soon after the exposure. The former may have increased to four times the number which were present before the exposure, but some hours afterwards their number begins to drop below the normal. The time which elapses before this drop begins, and the intensity of it, varies with the doses absorbed, and with the organs which were exposed. The increase at the beginning seems only to be due to a more rapid expulsion of the leucocytes, etc., from the cells which produced them. They empty their stores at a quicker rate. Provided the X-ray dose was not too strong, a recovery sets in gradually and the cells resume their normal function and rate of activity after some time. The blood may show its normal composition again in anything between from 3 to 90 days, according to the quantity of X rays which has been absorbed by it. When the region of the kidneys has been exposed the quantity of urine secreted increases, and so does the normal quantity of uric acid, sodium chloride, calcium, and other minerals contained in it.

The paralytic effects can be more clearly defined than the much disputed "stimulation." The dryness of the mouth and throat for instance, of which some patients may complain even after a very prolonged examination on the fluorescent screen, is due to a paralysis of the salivary glands. The function of the ovaries can be paralysed by moderate doses to relieve excessive hæmorrhage

Diseased or inflamed cells are slightly more susceptible to X rays than healthy ones, and are therefore eliminated at a quicker rate after exposures to moderate doses. It is likely that this is the cause why swellings or tumours begin to shrink. The healthy cells in the neighbourh od then find more room for expansion. The greater activity which can be noticed in the adjoining healthy tissues may be due partly to this, and partly also to the increased irritation due to the greater quantity of necrotic matter which has to be eliminated. The X-ray sickness which begins to appear after exposure to moderate or strong doses is most likely largely due to this cause too.

With doses of sufficient strength, the irritation becomes so violent that even organs like the skin, etc., become atrophied and shrink, or when the exposure was excessive, ulcers and abscesses begin to form.

Any of the various degrees of irritation caused by X rays, the temporary stimulation, temporary or permanent paralysis, atrophy, or even necrosis of some organs may be used therapeutically in suitable cases.

In the following pages I will try to give short abstracts of some articles which have been published in German about the experiences and results obtained with X-ray treatment in some diseases. References to the books and periodicals in which the original articles, with more details, the history of cases, etc., can be found, and the names of the authors, are given too.

Technique, Doses and Filters to be used.—As to the technique and doses with which the results have been obtained, I will mention here a few points which apply to the treatment of all internal diseases, to avoid repetitions and waste of space.

Hard rays are considered indispensable for the treatment of internal diseases. Tubes with equivalent spark gaps of 30 cm. and upwards, and filters of 0·5 mm. zinc or copper, are to be used in most cases. The anticathode skin distance should be 30 to 35 cm., and the doses reaching the skin should not exceed three-fourths of an erythema dose. Dosage by length of time is considered sufficient, but the efficiency of the tubes and apparatus should be controlled from time to time with Kienböck strips, Sabouraud pastilles or, preferably, an Iontoquantimeter. Intervals of not less than about eight weeks are necessary before the exposures may be repeated. In the few cases in which 3 to 4 mm. aluminium filters may be used, an interval of four to five weeks is considered sufficient.

When nothing else is stated, these general rules apply for the treatment of the various diseases to be described below, and only exceptions will be mentioned specially.

Tubercular Glands.—By Professor Stepp. (Salzmann, "Die Röntgen Behandlung innerer Krankheiten," pages 72–79.)

The great value of X rays in the treatment of tuberculosis of lymphatic glands has now been proved for so many years, and in such a large number of cases, that there can no longer be any doubt about their usefulness. Even

It is obvious that X rays cannot restore tissues which have already become soft and necrotic. When pus has formed in appreciable quantities, it has to be removed by an incision or with a syringe, but granulating tissues are highly sensitive to X rays, and begin to shrink and to form scars. When small parts just begin to turn soft, resorption frequently takes place after X rays have been applied, and even when pus has been discharged spontaneously through the skin, the healing process and the formation of scars of the remnants of tubercular granulating tissues will be accelerated under the influence of X rays. While pus is being formed profusely, X rays will bring no help. Though they will not make the condition worse, the exposures may be suspended, but they should be resumed again when the secretion begins to diminish.

The advantages of the X-ray treatment compared with surgical operations, are the following: There is no risk that the tubercle bacilli may be carried by tbe blood-stream to a large part of the body. Relapses are very few, and the formation of a lupus in the scar later on need not be feared. The chief advantage is the fact that the cosmetic effects of the X-ray treatment are decidedly better. This is of importance because tubercular glands often appear on the neck, and their removal by surgical operation frequently leaves disfiguring scars.

As to the technique, it is recommended to use windows with an aperture of 6 × 8 cm. It is sufficient if the seat of the disease receives one-third to one-half of the erythema dose, but care should be taken that the dose which reaches the skin should never exceed three-fourths of the erythema dose. With a good apparatus and tube, 35 to 40 per cent of the surface dose will under these conditions penetrate to a depth of 5 to 6 cm. If the glands are quite near the surface, an aluminium filter 4 mm. thick and a focus skin distance of 23 cm. may be sufficient. An exposure may be repeated after a rest of four to five weeks, but when a zinc filter has been used, the interval between two exposures should be six to eight weeks. A slight swelling of the glands will frequently be noticed within the first few days, but this will disappear soon afterwards, and the glands will then begin to shrink. If the dose applied was not excessive, X-ray treatment will leave no visible scar or mark. With children, the results are very good, and doses of 30 to 40 per cent of the erythema dose are usually sufficient. Ill effects have not been noticed.

About 82 per cent of the cases thus treated have either been completely cured, or at any rate very much improved; 10 per cent have been improved to a moderate extent. The X-ray treatment proved useless only in 3 per cent of the cases.

The same author describes on pages 80 to 88 his experiences and technique with

Tuberculosis of the Peritoneum.—Opinions as to the best method of treatment have changed repeatedly during the last decades. For some time, surgical operation was considered necessary, but later on it was found that more conservative methods, such as treatment with hot air, natural and

artificial sunlight, etc., gave almost equally good results, and that the prognosis of the disease was not as bad as was supposed for some time. Although a large number of favourable results obtained with X-ray treatment have already appeared in the medical literature, the advantages of it are not yet sufficiently known. Moderate doses of X rays accelerate the reduction of granulating tissues, and increase the tendency to form scars.

The distance of the peritoneum below the skin changes very much. On the abdomen it may be as small as 0·5 cm., and on the back as great as 8 or even 10 cm. It is therefore difficult to treat all the diseased parts of it with a dose of uniform intensity, but it is sufficient if they are subjected to about one-third of the erythema dose. On the abdomen this can be obtained with a 4 mm. aluminium filter and a focus skin distance of 23 cm., whilst on the back a 0·5 mm. zinc filter is necessary and a distance of 30 to 50 cm. Four windows, of 10 × 10 cm., or else two of 15 × 15 cm. each, can be used on the abdomen and on the back, but care must be taken that the cones of rays do not overlap when the larger sized windows are used. The doses applied to the skin should never exceed three-fourths of the erythema dose. No more than two windows are exposed on one day. After a rest of two days, another two can be exposed, so that each of the eight windows receives an exposure within 8 to 10 days. After an interval of six weeks the series may be repeated.

With the exception of peritonitis due to abscesses all forms of tuberculosis of the peritoneum are suitable for X-ray treatment. If greater quantities of fluid are present it is best to remove it by puncture. Exudative stages of peritonitis react best, and comparatively weak doses are sufficient. The dry stage with tendency to proliferation is more obstinate, and requires somewhat stronger doses and repeated exposures. Fever is no contra-indication provided that it is not due to tuberculosis of the lungs.

The author adds the history of some cases in which X-ray treatment restored the patients completely within a few months, after other forms of treatment had failed.

In the "Wiener klinische Wochenschrift," 1922, page 933, Professor Weibel, of Vienna, publishes a very favourable report about his experience in treating tuberculosis of the peritoneum and genital organs with X rays. Eighteen per cent of the cases treated did not recover, but 82 per cent were cured. Dr. Bircher, of Aarau, Switzerland, who was the first to suggest this kind of treatment, claims 98 out of 102 cases as cured.

Tuberculosis of the Lungs.—After it had been found that tuberculous diseases of the skin and of lymphatic glands near it can be cured by X rays, it was hoped that tuberculosis of the lungs could be cured too, and at a time when X rays of great penetrating power were not yet available, doses of increasing strength were tried with negative and sometimes disastrous results. It is now unanimously admitted that tubercle bacilli themselves cannot be killed, or even influenced, by X rays, but it has been found that in spite of this the X rays are a very valuable help in certain stages of tuberculosis of

Professor Bacmeister states (Salzmann, " Röntgen Behandlung innerer Krankheiten," *pages 58–71) that he treated over one thousand cases of* pulmonary tuberculosis with X rays during the last seven years in a sanatorium in the Black Forest, and describes some experiments on rabbits. The results of the latter are expressed in the following sentences :—

1. By using hard, filtered rays, an incipient tuberculosis in rabbits can be suppressed and an existing one can be cured.

2. Rapidly growing granulating tissues will begin to form scars under the *influence of X rays, but the tubercle bacilli cannot be influenced* by the X rays.

3. There is an optimum dose with which beneficial results can be obtained : small doses, with long intervals between the exposures, have no effect ; strong doses with short intervals aggravate the disease.

4. Artificially produced tuberculosis of the lungs can be cured when a correct technique is used.

In the explanations which follow, he states that only those cases have a good prospect of being cured by X rays, in which tubercular granulating tissues are being formed. They can be stimulated to form scars. But in addition to the X-ray treatment of the local seat of the disease, it is necessary to use fresh air, sunlight, diet, rest cure, etc., so that the resisting power of the patient's body is increased, and that no new local outbreaks will appear. X-ray treatment is only an additional valuable help to an existing healing tendency. If the latter is entirely absent, X rays will be of no use. When the bacilli are so virulent, or the resisting power of the patient so low, that the disease is progressing rapidly and ulcers are formed, X rays will accelerate the decay in cases of pulmonary tuberculosis.

As to the technique, he recommends the use of five skin windows, with an aperture of 10 × 10 cm. Three can be applied on the right side of the chest, two on the left side, and a similar number on the back. One-twelfth of the erythema dose is to be given through each of these windows, and this dose can be produced in about 5 minutes. In each sitting only one window is exposed. If this is tolerated well, as many as three sittings can be given per week. Small increases in temperature, lasting for a few hours only, and a slight increase in coughing and the expectoration do not matter, but a rise in temperature of longer duration would be an indication that the optimum dose has been exceeded, or that the intervals between two exposures have been too short. In this manner one side of the lungs is treated first from the front and then from behind. After a rest of eight days, the other side of the lungs is treated in the same way. If the symptoms—increase of appetite, weight, etc.—are favourable, another series of sittings is given, and either the intervals between two sittings may be reduced a little, or else the doses may be slightly increased. Symptoms of X-ray sickness will scarcely be noticeable. The favourable symptoms begin to appear only after some time.

Professor De la Camp, of Freiburg, comes to the same conc[illegible] (*Strahlen Therapie*, Vol. 15, pages 427–435), and recommends q

slowly to one-fifth of the erythema dose. He, too, states distinctly, that only those cases of pulmonary tuberculosis should be treated with X rays, which are progressing slowly, or show a tendency to remain stationary or latent, whereas in miliary and exudative forms X rays cannot bring any improvement.

Tuberculosis of the Larynx. ("Münchener medizin. Wochenschrift," 1922, page 1572.)—Twelve cases, in the initial stage of tuberculosis, have been cured by X-ray treatment alone. In other cases X rays proved a great help to an existing healing tendency. They accelerated the formation of scars, etc., but they could not replace or supersede the other therapeutic agencies, like fresh air, sunshine, rest, diet, etc. In the exudative forms, when perichondritis is present and when ulcers have formed, the X rays are no help and may even aggravate the condition.

Every second day about two-thirds of an erythema dose are applied through windows with a diameter of 4 cm., an aluminium filter 4 mm. thick, and with a focus skin distance of 24 cm. One of these exposures is given on the right, one on the left, and the third in front of the larynx. In the following week three similar exposures are given. After these 6 exposures the X-ray treatment is stopped for at least three weeks. If the clinical symptoms are favourable the series of 6 exposures is repeated.

Out of 49 cases which were treated, in addition to X rays, partly with krysolgan, partly with cautery or curetting, 10 were completely cured. In 22 cases the improvement was very great. In 9 cases there was no improvement, and 4 cases, in the exudating stage, with extensive ulcers, became worse. X rays were applied in these cases chiefly to relieve pain.

Bronchial Asthma.*—The idea that X rays should be capable of beneficially* influencing this otherwise so often incurable complaint looks incredible at first sight, and most readers are sure to shake their heads.

In 1906, Dr. Schilling reported at the Congress of Internal Medicine in Munich, as follows: "My attention was drawn accidentally to the fact that X rays might have an influence on asthma. A patient suffering from bronchial exudation, with such severe asthmatic attacks that he could retain neither urine nor fæces during these attacks, was examined diagnostically on the screen. He reported afterwards, that on the day and night following this examination, he had no expectoration, whereas previously he expectorated some 250 c.cm. within twenty-four hours. The quantity dropped to about 40 c.cm. per day during the following week, and the asthmatic attacks did not return. I then treated 9 other patients, and noticed in all cases a considerable improvement in the condition of the patients."

The method was then tried by others. The total number of patients who were treated for asthma by exposing their lungs to the action of the X rays does not, however, seem to have been great for some time. The doses used were not mentioned in those early years. Some specialists reported about 25 per cent of cures, and a greater percentage of decided improvements, but some complete failures were also admitted, and there was a controversy

whether the successes were due in some cases to suggestion, and in others tumours, etc., which caused mechanical pressure, and which may have be reduced in size by the X rays.

Another accident directed the attention of Dr. Gródel, of Nauheim, another method. A patient was sent to him to be treated with X rays chronic lymphatic leukæmia. At the time this treatment was applied I Gródel was ignorant of the fact that this patient was a victim of asthma attacks. Nine months after the X-ray treatment he returned, and report as a curiosity, that he had had no more asthmatic attacks, and then only I Gródel learned that he had suffered severely during the last sixteen years fr this complaint.

Dr. Gródel followed the matter up, and reported in 1920 and 1921 abo 71 patients suffering from asthma, whose spleen was exposed to X rays. these, 10 patients did not report themselves again.

In 7 patients no improvement was noticeable.
,, 15 ,, the results were good.
,, 12 ,, ,, ,, very good, and
,, 27 ,, ,, ,, excellent.

All these patients had tried other remedies before, and some had be treated by nose specialists too. Most of them had suffered from asthma attacks for more than ten years, some of them since their childhood. Wi nearly all of them the expectoration became more liquid and copious and t breathing easier, the attacks ceased or became less frequent.

Dr. Gródel noticed that *all* those patients who were attacked by the X-r sickness benefited by the treatment, and the improvement was in proporti to the severity of the X-ray sickness. *None* of the patients who escaped t sickness entirely had a material benefit from this treatment. It is unlike that this is a mere accident, but it is difficult to give a satisfactory explanatic Either the secretion of the spleen may have become more copious after it h been irritated by the X rays, or else there may be some cells which produ toxins similar to those which cause hay fever, and these cells may have be paralysed or destroyed by the action of the rays.

Dr. Gródel used one window, 12 × 12 cm. above the spleen, a foc skin distance of 23 cm., and a boiling water tube suitable for deep therap The dose applied to the skin was a little below the erythema dose, and estimates that the spleen may have been reached by about one-third of t erythema dose. If no improvement was noticeable within a few days, second exposure was given after an interval of *not less* than 3 weeks, preferab more. More than three exposures were never applied.

In two cases, the first and second exposure produced a decided improv ment, each lasting for several months, but a third exposure proved a failu and Dr. Gródel suspects that the doses may have been too strong, and m already have had a paralysing effect. He considers it possible that in the cases, where an improvement followed after an exposure of the thorax, th result may have been due, too, to X rays which reached the spleen indirectl

Many other reports have appeared since then confirming the good results. Dr. Marum relates that in the X-ray department of the Hospital of the Municipality of Cologne 40 cases of bronchial asthma have been treated between 1918 and 1923. Of these, 32·5 per cent were cured, 27·5 per cent very much improved (the attacks ceased, but a slight coughing and shortness of breath remained, which did not interfere any more with the normal occupation of the patients), 20 per cent were improved. In 12·5 per cent there was no improvement, and 7·5 per cent did not report themselves again. Of those patients who suffered from asthma for ten years or longer, 30·8 per cent only were cured or much improved, whereas of those patients in whom the disease had developed only recently, during the last twelve months, 100 per cent were cured.

The exposure lasts only a few minutes, and has to be repeated twice or three times at intervals of three weeks. The roots of the lungs are exposed to about one-fifth of the erythema dose from front and back. The expectoration increases. The rapid onset of the improvement, and the absence of unpleasant effects, are an advantage of the X-ray treatment.

Diseases of the Blood.—The great changes produced in the blood by exposures to X rays, of sufficient intensity have been mentioned already. They become specially apparent when some of the blood-forming organs have been exposed, but that the blood itself is sensitive too has been proved repeatedly by exposing for instance the combs of cocks, the ears of rabbits, etc. These changes are therapeutically useful. Dr. Herzog and Professor Morawitz describe (in Salzmann, "Röntgen Behandlung innerer Krankheiten," on pages 328 to 352) the results and experiences obtained in some diseases of the blood.

Leukæmia.—Drs. Pusey and Senn, of Chicago, reported in 1902 already that patients suffering from leukæmia can be restored apparently to perfect health by exposing their spleen to moderate doses of X rays. This has since been confirmed by many others, but it has also been proved that the improvement is not permanent. It may last a long time after the first series of exposures, but the symptoms reappear, and after subsequent X-ray treatment the periods of improvement will be of shorter duration. The intervals between the relapses will gradually become shorter and shorter, and ultimately the X rays prove useless. Nevertheless, patients can enjoy their lives, and even resume their normal occupation and work for a considerable time. Several cases are recorded in which the patients have been kept alive by the X-ray treatment for 8 to 10 years, but these are exceptions; the average prolongation of life due to the X-ray treatment does not seem to exceed about two years, but it is unanimously admitted that health can be restored for a considerable time, and it has to be remembered that there is no other remedy known which has proved of any, even temporary, value against this disease.

There is a large number of reports of cases by different authors. As to the technique, the spleen is invariably exposed by all of them; 2 to 3 skin windows are used, which may all be exposed on one day. The doses given

through each are chosen so that one-fourth to one-third of the erythema dose should reach the spleen. Aluminium filters 4 mm. thick are considered sufficient by many, and the exposures should be repeated after four weeks. Some authors recommend exposing the marrow bones too, and a few even the liver and lymphatic glands. There is unanimity that strong doses should be avoided; a severe X-ray sickness might even be dangerous for patients suffering from this disease.

The shrinking of the swelling of the spleen begins to become noticeable within a few hours already after the first exposure. An improvement of the general condition follows, the body weight increases, and pain, pressure, lassitude, headache, sleeplessness, etc., disappear. The changes in the blood become apparent, the number of leucocytes increases for a few hours, but begins to drop soon. The X-ray treatment should be stopped a little while before their number approaches the normal, because the full effect becomes noticeable only some time afterwards. The follicles of the lymphatic glands become small, and contain comparatively few lymphocytes. The number of red blood-corpuscles and the quantity of hæmoglobin increase. The secretion of uric acid, purin bases, phosphoric acid, etc., increases considerably, and gradually reaches the normal. Cases of acute leukæmia are not suitable for X-ray treatment.

A detailed report about the results of X-ray treatment in **Lymphogranulomas** and **Hodgkin's Disease** appeared in the "Münchener medizin. Wochenschrift," 1923, pages 725–727. Dr. Chaoul states that, on an average, life can be prolonged one to two, sometimes three years. Permanent cures have not yet been observed. He gives a warning against strong doses, and recommends using 4 large windows, one in front on the neck and chest, including the front part of the armpits, the second on the abdomen, the third on the back of neck and chest, and the fourth on the lower part of the back. Focus skin distance 40 to 45 cm., 1 mm. copper filter. Each of the four windows is exposed to 10 per cent of the erythema dose. After a rest of one or two days the exposures are repeated; a rest of six days is then given before the exposures are repeated once more. This is continued until each of the 4 windows has received a total of 60 to 80 per cent of the erythema dose in the course of 6 to 8 weeks. Within this time the glands almost invariably disappear. After three months the series of sittings are repeated, and a year afterwards a third series may be applied as a prophylactic precaution.

In this way a slow resorption of the tumours takes place without any X-ray sickness. Twelve patients have been treated in this way; one died 5 months later, with a carcinoma in the stomach; another after 2¾ years with a sarcoma in the neck. One showed a relapse after 8 months, another after 2½ years, and the remaining 8 are fit to work and free from relapses since 2½ years.

Cases of tubercular or syphilitic granulomas are unsuitable for X-ray treatment.

Diseases of the Thymus (Salzmann, pages 193–195).—The thymus is

very sensitive to X rays. When it has been subjected to about one half of the erythema dose, a shrinking of the glands can be noticed after 3½ hours already, and within a few days the total loss in size may amount to as much as 90 per cent. The recovery begins within about a fortnight, and is complete after thirty days. If the thymus is reached by a full erythema dose, it may shrink completely, and the power of regeneration may be gone entirely. As this would entail the gravest consequences for the whole lifetime of the patient, such an overdose must be avoided most carefully.

One skin window is to be applied in front, two from the back, and in acute cases one-half of the erythema dose is given to the skin through each of these three windows. In chronic or subacute cases, it is better to begin with one-fourth of the erythema dose, and to repeat the treatment after three or four weeks.

In all the cases published up to now, the X-ray treatment was completely successful, and as the mortality with surgical operations may exceed 30 per cent in these cases, it is highly desirable that X rays should invariably be tried before an operation is risked.

Tumours of the Hypophysis.—The diseases due to an abnormal or subnormal function of the hypophysis have been brought to a standstill, or cured, by X rays in a fair number of cases. The hyperfunction causes the abnormal growth of the bones of the hands and feet, a swelling of the tongue, nose, lips and ears, and the pressure on the optic nerve causes disorders of the eyesight. The subnormal function, due to the presence of tumours, causes abnormal layers of fat to form in the region of the mammæ, the hip and abdomen, and atrophy of the sexual organs and their functions.

The mortality of surgical operation is high, the results are uncertain. Some 30 cases have been published so far in which X rays have been used. In three-fourths of these cases the progress of the malady was stopped, many of the symptoms disappeared, and the eyesight was improved. The decrease or increase of the diameter of the field of vision allows a correct judgment of the changes taking place in the hypophysis. In about half the number of cases treated, eyesight was so far restored that the patients could resume their normal work, and in another one-fourth of the cases it was decidedly improved. In 8 cases, chiefly elderly patients, the X-ray treatment brought no improvement.

As to the technique, the distance from the temples and the forehead to the hypophysis is about 7 cm. It is recommended to use six skin windows of 5×5 cm. each. With the necessary intervals, they cover a belt stretching from ear to ear. Each of these windows is given an exposure equal to three-fourths of the erythema dose. Two windows are exposed on one day. After an interval of five to eight days two more windows are exposed. The hypophysis will be reached by about 20 per cent of the doses applied to the skin, and will thus receive altogether about two-thirds of an erythema dose. The first series of exposures will be finished in two to three weeks, and in all cases which react favourably to the X-ray treatment, an increase in the diameter of the field of vision will be noticeable after that

time. The exposures should be stopped then, as too large a dose may cause atrophy of the hypophysis, with serious consequences. It is advisable, however, to apply another series of exposures after a rest of three to four months.

In cases of subnormal function stronger doses have to be used, because it is likely that a carcinoma or sarcoma may be the cause. The full erythema dose is therefore given to each of the six windows, with intervals of two to three days between each. An additional window may be exposed through the upper part of the occiput. The hypophysis will then have been reached altogether by 170 per cent of the erythema dose. If there is no improvement, it is advisable to repeat the series of exposures after six weeks, but if an improvement in the field of vision is noticeable, an interval of three months should be allowed before a second series of exposures is commenced. Epilation will take place, but the hairs will grow again within about three months. Severe symptoms of X-ray sickness may appear too.

In those cases in which the X-ray treatment is successful the abnormal quantity of fat begins to diminish, hairs of the beard, in the armpits, and on the genital organs begin to grow again, and an improvement is noticeable in the intellectual activity of the patients.

Professor Kontschalowsky and Dr. Eisenstein, of Moscow, report successful cases in *Strahlen Therapie*, Vol. 14, page 943: A woman, 32 years old, with typical enlargement of the face and extremities, severe headache, blind in the right eye, and the diameter of the field of vision of the left eye reduced to one-half. One window each on the right and left temple, 3 mm. aluminium filter, several exposures with moderate doses, so that each window received a total of one-half of the erythema dose. After four weeks' rest, the series of exposures were repeated. Result: Three days after the start of the X-ray exposures the headache ceased completely, eleven days afterwards the patient could see again with her right eye, and the eyesight increased steadily during the six months following.

Exposure of the hypophysis has also a marked influence on the functions of the ovaries. In Vienna, 25 patients suffering from headache, vertigo, etc due to the climacterium were cured of these complaints, and 54 patient suffering from amenorrhœa, 52 suffering from dysmenorrhœa, and 51 sufferin from climacteric complaints were treated with repeated applications of sma doses of X rays to their hypophysis, and 50 to 80 per cent were greatl improved by this treatment.

Chronic Prostatic Hypertrophy.—In the "American Journal of Röntgen ology," 1923, pages 810–814, Dr. J. Th. Stevens relates his experience i treating 33 cases of hypertrophy of the prostatic gland. Most of them wei in such a condition that surgery could never have been resorted to with an hope of their living through the operation. There was one failure, and tw deaths, one due to cerebral hæmorrhage and the other to cardiac failure In 30 out of the 33 cases the treatment met with success; the retention an the frequency, the pain, the bleeding, etc., were relieved. In 3 of the case the gland had returned to normal size; in 27 cases it was reduced on a

average to one-third of the size it had at the beginning of the treatment, an instead of being hard it became soft to the touch.

Four to eight windows were exposed—two to four over the symphysi pubis and one or two to the right and left of the anus over the gluteal muscle Over each area the rays were centred towards the prostatic field. 40 cm focus skin distance, 6 mm. aluminium filter, and four-fifths of the erythem dose applied to each window. One or two of these series of exposures wer given. The treatment did not cause shock, hæmorrhage, uræmia, etc., an there is no mortality that can be traced to it. Should X-ray treatment fai surgery can still be substituted. Radiation does not produce any conditio which interferes with surgical removal of the gland.

Exophthalmic Goitre (Salzmann, 166–183).—As this disease is frequentl caused by a hypersecretion of the thyroid gland, the help of a surgeon i called in when treatment with drugs, etc., fails. When the influence c X rays on the secretion became known, they were tried too. The result of nearly 1000 cases treated with them during the last ten years are know now, and a comparison with surgical operations shows that the results a about equally good. About 50 per cent of the cases can be completely cure 44 per cent considerably improved, and only 5 per cent proved refractory These total failures are confined chiefly to elderly patients, suffering from th disease for several years. Young patients, acute and subacute cases whic have developed recently, react best.

The number of relapses seems to be the same, too, both with surgic operation and with X-ray treatment, and varies between 10 and 20 per cent but with surgical operation there is a mortality of nearly 5 per cent, wherea with X-ray treatment it is nil, and the patients need not even stay in a hospit or clinic. For these reasons the X-ray treatment should be tried before a operation is resorted to.

As to the technique, large doses have to be avoided. One-half, or eve one-third only, of an erythema dose is given in such a way that in additio to the thyroid gland the thymus is also reached. Tubes with an equivalen spark of 25 cm., and aluminium filters 3 mm. thick, are considered sufficien If the patients are very sensitive, the exposure may be spread over two day Formerly two skin windows were used, one on either side; nowadays onl one is applied, from the front. The region of the parotids has to be carefull protected. The exposures should be repeated after 3½ to 4 weeks; four to fiv exposures are usually sufficient. In some cases double the number is require but more than ten exposures should not be given.

The first improvement is noticeable in the nervous symptoms. After th second or third exposure, the patients feel better and fit to work. Th frequency of the pulse begins to return to nearly the normal, the body weigh increases, the exophthalmos follows last in showing an improvement in most cases it does not recede completely. The reason why only

fact that about 98 per cent of all patients suffering from this disease are females proves that, in addition to the thyroid gland, the ovaries may contribute to the symptoms too. (See also *Strahlen Therapie*, Vol. 15, pages 450-457.)

In **Ischias, Trigeminal Neuralgia, Arthritis,** some diseases of the **Heart and Stomach,** pain has been relieved with X-ray treatment. In **Diabetes, Pernicious Anæmia and Epilepsy** it has been tried repeatedly, but so far without any success worth mentioning.

Diseases of the Hair (" Münchener medizin. Wochenschrift," 1922, page 1430).—The Sabouraud and Kienböck Chromo Radiometers are based on the dose which causes a temporary paralysis of the follicles of the hairs. Men whose faces have been exposed to a Sabouraud Teinte B, or a Kienböck 11 x dose, notice a somewhat quicker rate of growth of the beard during the first week after the exposure; they have to shave a little more frequently. Towards the end of the second week paralysis sets in, the hairs do not grow any more, and towards the end of the third week they fall out. Six weeks afterwards they begin to grow again. Holzknecht found that this is not an accident, but that the regrowth is due to the irritation caused by the X rays, and that the hairs will also begin to regrow when bald patches due to alopecia areata are exposed to the epilation dose. But the head first became completely bald, and it took several months before the hairs of women had reached a fairly normal appearance again.

Dr. Thedering has shown soon afterwards that the full epilation dose is not at all necessary, one-fifth of it is sufficient to start the regrowth of the hairs on these bald patches. The whole scalp is exposed from four different centres, under a 1 or 2 mm. aluminium filter, so that every part receives a dose of one-tenth to one-fifth of the epilation dose (1 to 2 x of the Kienböck quantimeter). These exposures are repeated with intervals of one to three weeks, till the hairs begin to grow again, which is usually the case after three to five series of these exposures have been given. The healthy hairs are not affected by this treatment, and do not fall out. The parasites, which are most likely the cause of the disease, and which infect the whole area of the scalp, are evidently killed, as no relapses have been observed so far, after this kind of treatment had been applied.

TABLES.

The following tables are given to save the operators, who have plenty of other things to attend to, some time and calculations. Most of them are taken from works by Drs. Christen, Dessauer, Friedrich, Holzknecht, Kaye, March, Schreuss, Seitz and Wintz, Staunig, Voltz, Wetterer, etc. I believe them to be reliable and useful, but must decline legal responsibility if it should be found that any error is contained in them.

The large number of figures may frighten many readers at first sight, but they will soon find that for their own special requirements only a few of the tables are important. Different operators will find different tables useful. For instance, those who use most frequently a distance of 23 cm. between anticathode and skin will find Table No. 6 convenient to find the differences, which are made necessary in the duration of the exposures when another focus distance is used; but those who, as a rule, use 20 or 30 cm. as focus skin distance, will find Table No. 5 more convenient.

Explanations of the tables are added, though some of these have been given in previous pages. The tables may also be some help to corroborate special tables compiled for the individual requirements by the operator.

General Tables.

The first group shows the relations between spark length, voltage and wave length. The number of volts required to cause a discharge through a certain length of air varies, however, widely with the shape and diameter of the electrodes used, and to a slight extent also with the humidity and the pressure of the air. About 35,000 volts are sufficient to cause a discharge through an air gap 50 mm. wide, when the + pole is connected with a point and the — with a plate, but about three times as many volts are required when balls of 5 cm. diameter are used as electrodes for both poles. The number of kilo volts required to start a discharge through an air space of :—

5	10	15	20	cm. will be *approximately* :—
30	60	88	110	K.V. when the electrodes consist of a point and a plate.
47	76	98	121	K.V. when both electrodes consist of points.
124	190	228		K.V. when both electrodes consist of balls of 10 cm. diam.
138	245			K.V. when both electrodes consist of balls of 25 cm. diam.

The length of an *equivalent spark gap* will also have a totally different value in volts, according to the shape and diameter of the electrodes used as terminals. An equivalent spark 10 cm. long will represent approximately 60 K.V., when the electrodes consist of a + point and — plate, but about 190 K.V. when two balls of 10 cm. diameter each are used as electrodes. Whenever an equivalent spark is mentioned in these pages, it refers to + point and — plate. The length of the equivalent spark of a given tube varies also a little with the resistance of the secondary winding of the coil or transformer on which it is used.

The spark lengths can therefore give only an approximate idea of the number of volts prevailing on the terminals, and tables compiled by various authors :

some difference. The voltages indicated by kilo voltmeters on the terminals of a transformer are not reliable. They vary with the frequency and invariably indicate more volts than are actually used in the tube, because the former are measured on *open* circuit, and losses are bound to occur through brush discharges, spark gaps, or valve tubes. The voltages used in the tube, on *closed* circuit, can be found out much more accurately with a spectrometer.

Table No. 1 shows the relation between the spark length and the corresponding number of volts prevailing on the terminals of a spark coil or transformer, if the sparks can discharge between a + point and a — plate.

Table No. 2 shows the relation between the number of volts applied to the terminals of the tube, and the boundary wave length.

Table No. 3 shows the relation between the wave length and the thickness of aluminium which will reduce the intensity of X rays to one-half. It enables us to find the wave length indirectly with an absorption meter.

Table No. 4 shows the wave length, the number of K.V. prevailing on the terminals of the tube, and the corresponding *approximate* number of K.V. prevailing on the terminals of the spark coil or transformer.

No. 1.				No. 2.		No. 3.	
Spark length in mm. between							
Balls of 25 mm. diam.	Balls of 100 mm. diam.	Point and plate	Kilo volts	Kilo volts on terminals of X-ray tube	Boundary wave length of radiations in Ångström Units	Boundary wave length in A.U.	Absorption meter in mm. of aluminium
4·2	4·6	17	15	27·5	0·45	1·0	0·025
5·8	6·2	24	20	28·1	0·44	0·597	0·1
9·5	9·5	40	30	29·5	0·42	0·462	0·2
14·0	12·9	58	40	31·0	0·40	0·397	0·25
20·0	16·5	80	50	32·6	0·38	0·357	0·4
28·0	20·2	104	60	34·4	0·36	0·329	0·5
40·0	24·2	132	70	36·5	0·34	0·309	0·6
	28·4	163	80	38·6	0·32	0·290	0·7
	32·8	196	90	41·3	0·30	0·276	0·8
	37·5	230	100	44·2	0·28	0·265	0·9
	42·5	270	110	47·7	0·26	0·254	1·0
	47·8	310	120	51·5	0·24	0·244	1·1
	53·5	350	130	56·1	0·22	0·238	1·2
	59·7	390	140	62·0	0·20	0·230	1·3
	66·4	430	150	68·7	0·18	0·225	1·4
	73·7	470	160	77·3	0·16	0·213	1·6
	81·6	—	170	88·4	0·14	0·205	1·8
	90·3	—	180	123·0	0·10	0·197	2·0
	100·0	—	190	155·0	0·08	0·181	2·5
	111·0	—	200	177·0	0·07	0·169	3·0
				206·0	0·06	0·160	3·5
				246·0	0·05	0·152	4·0

No. 4.

Ångström units	Kilo volts on tube.	Equivalent spark gap	Kilo volts on terminals of coil or transformer
0·21	59	about 12·0 cm.	about 75
0·20	62		
0·19	65	,, 13·5 ,,	,, 80
0·18	68·5		
0·17	73	,, 15·5 ,,	,, 90
0·16	77·5	,, 16·0 ,,	,, 93
0·15	82·5	,, 17·5 ,,	,, 99
0·14	88·5	,, 18·5 ,,	,, 105·5
0·13	95·0		
0·12	103·0	,, 22·0 ,,	,, 123·5
0·11	112·5		
0·10	123·6	,, 28·0	,, 148
0·09	138		

Nos. 5 and 6 show how the distance between the anticathode and the object influence the intensity of the X rays reaching the object, and the time of the exposure required to produce a certain dose with increasing distance; No. 5 starts with a distance of 20 cm., No. 6 with one of 23 cm.

No. 5.			No. 6.		
Distance in cm.	Intensity	Time	Distance in cm.	Intensity	Time
20	100	100	23	100	100
25	63·5	157	25	85	118
30	44·5	224	30	59	170
35	32·6	306	35	43	232
40	25·0	400	40	33	302
45	19·8	505	45	26	383
50	16·0	625	50	21	473
55	13·2	755	55	17·5	572
60	11·1	900	60	14·7	681
65	9·4	1060	65	12·5	799
70	8·2	1220	70	10·8	926
75	7·1	1410	75	9·4	1063
80	6·25	1600	80	8·3	1200
85	5·5	1820	85	7·3	1366
90	4·9	2040	90	6·5	1540
95	4·45	2240	95	5·9	1709
100	4·0	2500	100	5·3	1889

No. 7 shows the influence of the focus skin distance on the duration of the exposure in another way. If a certain effect is produced with a

focus skin distance of 23 cm.	in	25	30	35	40	minutes, the time
required with a distance of 30 cm.	will be	43	51	59	68	,,
,, ,, 35 cm.	,,	58	70	82	93	,,
,, ,, 50 cm.	,,	118	145	166	189	,,

No. 8 explains the same thing in another manner; it shows how the intensities of X rays prevailing *below the skin* vary with the distance used. The figures given on the left side of the central ray show the distance in cm. between the anticathode and skin, and below the skin. The figures on the right side of the central ray show the intensities prevailing at various points, if the intensity on the skin is taken as 100. With the distance of 50 cm. the exposure required will be four times as long as with a distance of 25 cm. only, but the percentage of the surface intensity obtained below the skin increases.

No. 8.

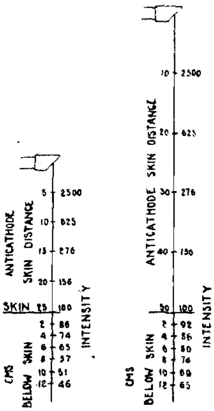


Table No. 9 shows how the penetrating power of the rays emitted by one and the same tube rises, *without any alteration in the vacuum in the case of a gas tube, or the heating current in case of a Coolidge tube, taking place,* when the number of M.A. is *raised by raising the E.M.F. on the terminals of the tube* (this is done by raising the strength of current in the primary circuit of a coil or a transformer).

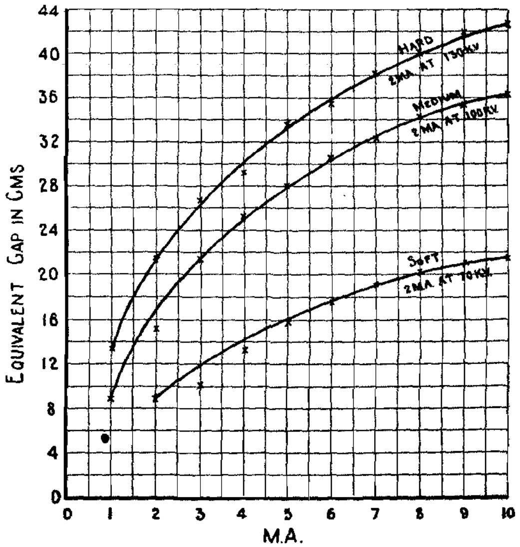
This variation of quality is due to the fact that we have to change the E.M.F. on the ends of the tube, and therefore the speed of the cathode stream, if we wish to alter the current in the tube. Thus if we compile a table of values of M.A. and corresponding equivalent spark gaps, or better, boundary wave lengths for any particular gas or Coolidge tube under definite conditions of vacuum or filament heating current, we can select a radiation of particular quality by merely adjusting our secondary current to the corresponding value (see also page 37).

The changes taking place become most obvious if we plot the values in the form of a graph. The table and graph here shown have been taken with a spark coil and are merely examples, as the curves vary slightly with individual tubes and apparatus used. The labour involved is not large and is well worth while. A check on the constancy of conditions in the tube is afforded by an observation of the primary current. Thus, if we have determined the M.A. values of equivalent spark for a gas or a Coolidge tube, and have noted that, let us say, 5 M.A. passed when there were 4 ampères in the primary of the coil, we can always reset to 5 M.A., and note whether the primary current is 4 ampères. Having ascertained this, we know that the tube is in the same state as it was when calibrated, and can select the quality of rays which is best suited for the case by altering the milliampèreage.

With soft tubes the equivalent spark gap rises about 100 per cent when the current is raised from 2 to 5 M.A., with medium and hard tubes it rises about 75 per cent under the same conditions.

No. 9.

M.A.	Equivalent gap in cm.		
	Soft tube 2 M.A. 70 K.V.	Med. tube 2 M.A. 100 K.V.	Hard tube 2 M.A. 130 K.V.
1	—	8·8	13·3
2	8·8	15·2	21·6
3	10·2	21·6	26·7
4	13·3	25·4	29·2
5	15·9	28·0	33·6
6	17·8	30·5	35·5
7	19·2	32·3	38·1
8	20·3	34·2	40·0
9	21·0	35·5	41·9
10	21·6	36·2	42·5



Diagnostic Tables.

No. 10 shows the boundary wave length or quality of the rays whicl should be used with various thicknesses of the body to obtain the greates amount of details on the negatives. It shows also the number of M.A. seconds

No. 10.

Thickness of object in cm.	Wave length in A. units	M.A. seconds	Thickness of object in cm.	Wave length in A. units	M.A. seconds
4	0·43	80	17	0·27	80
5	0·41	75	18	0·27	90
6	0·39	68	19	0·26	100
7	0·37	62	20	0·25	110
8	0·36	58	21	0·25	120
9	0·34	55	22	0·24	126
10	0·33	52	23	0·23	134
11	0·32	50	24	0·23	140
12	0·31	48	25	0·22	144
13	0·30	50	26	0·22	148
14	0·29	52	27	0·22	152
15	0·28	60	28	0·21	155
16	0·28	70	29	0·21	157
			30	0·21	160

No. 11.

Object	Thickness in cm.	(λ_0) in A U.	Product M.A. x Secs Gas Tube	Coolidge	Remarks
Stomach and Intestines ..	14–16 17–19 20–24	0·23 0·22 0·21	55 70 80	104 133 150	80 cm. Focus plate.
Gall-bladder .. Kidneys ..	14–16 17–19 20–24	0·28 0·26 0·24	150 180 250	285 340 470	Cylinder diaphragm.
Antrum .. (Skull) ..	16–18 19–21 22–24	0·24 0·23 0·22	240 280 320	460 530 610	Cylinder diaphragm. *No* screen.
Lungs	18–21 22–23 24–26	0·20 0·19 0·18	40 45 50	76 85 95	80 cm. Focus plate. *No* screen.
Temporal ..	..	0·25	200	380	*No* screen.
Incisors .. .. Molars	.. ..	0·30 0·27	150 150	280 280	Film in mouth. *No* screen.
Sternum (frontal) Scapula ,, Hip-joint ..	.. .. ..	0·26 0·28 0·25	200 160 200	380 300 380	Cylinder diaphragm.

which should be used to obtain correctly-exposed negatives with these thicknesses, when the distance between anticathode and plate is 60 cm., when an interrupterless high tension rectifier, a gas tube and one intensifying screen are used. When a spark coil and interrupter are used, about one-third of the number of M.A. seconds mentioned will be found sufficient. With a Coolidge tube the number of M.A. seconds has to be doubled.

No. 11 shows a similar table for a few special parts of the human body which require either other distances or else somewhat harder rays than would correspond with their thicknesses, because bones have to be traversed.

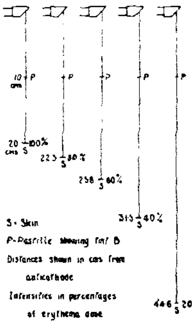
Therapeutic Tables.

No. 12 shows how *fractions* of the epilation dose can be measured with the Sabouraud pastilles, by *increasing* the distance between pastille and skin. When the pastille assumes Teinte B, with a focus pastille distance of 10 cm., the epilation dose will be reached when the *pastille skin distance* is also 10 cm., but when the latter is *increased*

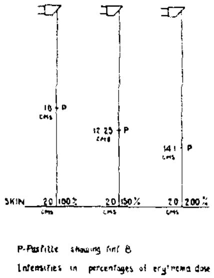
from	10 to 12·3	15·8	21·6	34·6 cm.		
only	100	80	60	40	20	per cent

of the epilation dose will be obtained on the skin when the pastille has assumed Teinte B.

No. 12.



No. 13.



No. 13 shows how *multiples* of the epilation dose can be measured with Sabouraud pastilles, by *reducing the distance between pastille and skin.*

No. 14. The relation between aluminium filters and filters of zinc or brass is as follows :—

0·1 mm.	of zinc, brass or copper absorb about as much as	2·5	mm. of aluminium.
0·2 mm.		5	mm. ,,
0.3 mm.		7·5	mm. ,,
0·4 mm.		10	mm. ,,
0·5 mm.		12·5	mm. ,,
1·0 mm.		25	mm. ,,

No. 15 shows how the intensity of the rays diminishes after they have passed filters of various materials and thicknesses, and how the composition of the rays is changed by passing a filter.

In the first line the thickness and material of the filter is mentioned, in the second line the reduction in intensities, and in the third line the increase in the percentage of hard rays, as indicated by the absorption meter.

		Aluminium.				Zinc.	Copper.
	0	1	2	3	4	0·5	1·0 mm.
Intensities ..	100	70	50	40	35	12	8
Absorption meter		1·9	2	2·25	2·5	3·5	4 cm. aluminium.

No. 16 shows how the dose which is necessary for epilation varies when the filter and the quality of the rays are varied.

Quality of the rays measured on—

Absorption meter	1·0	1·6	1·8	2·2	2·5	4 mm. aluminium
Spectrometer ..	0·6	0·53	0·49	0·43	0·39	0·36 A. U.
Filter	0·0		0·5	2·0	3·0	11 mm. aluminium
Fraction of erythema dose necessary to produce epilation ..	0·8		0·7	0·65	0·6	0·5

No. 17 shows the duration of exposure which is necessary to produce an erythema with various filters when tubes having an equivalent spark gap of 25 cm. are used and when unfiltered radiation would set up an erythema in three minutes.

Filter	0·0	0·5	2·0	4·0	12·0 mm. aluminium.
Epilation dose in	3	4·5	8·0	12·0	45·0 minutes.

When hard tubes with an equivalent spark gap of nearly 40 cm. are used, the percentage depth dose of the rays obtained below a filter of 0·5 mm. brass will be increased by 5 per cent only when the thickness of the filter is increased from 0·5 mm. to 1·0 mm., and by 10 per cent if the thickness is increased to 1·5 mm., but the duration of the exposure would have to be about 2½ times as long with the 1 mm., and nearly 4 times as long with the 1·5 mm. filter.

The percentage depth dose of the rays emitted by the same tube will be reduced by only about 5 per cent when the 0·5 mm. brass filter is replaced by one of 0·2 mm., and the duration of the exposure can then be reduced nearly 50 per cent.

No. 18 shows the reading which the chromo radiometers of Sabouraud or Kienböck indicate with various qualities of the X rays and with various filters when an erythema has been produced.

No. 19 shows the reading indicated by the Sabouraud or Kienböck chromo radiometers, with various qualities of the rays, when *fractions* of the erythema dose have been given.

No. 18.

A.U.		Mm. of alum.	Filter	Erythema dose Sabouraud	Kienböck
0·587	Quality of rays measured with absorption meter	1·0	0	1·0 Teinte B	7·5 x
0·519		1·6	0	1·2 ,, ,,	15 x
0·493		1·8	0·5 mm.	1·6 ,, ,,	27 x
0·462		2·0	1·0 alum.	1·8 ,, ,,	35 x
0·430		2·25	2·0 ,,	2·0 ,, ,,	50 x
0·397		2·5	3·0 ,,	2·5 ,, ,,	65 x
0·397		2·5	4·0 ,,	3·0 ,, ,,	70 x
0·357		4·0	0·5 zinc	4·0 ,, ,,	

No. 19.

Fractions of the erythema dose: 1 0·9 0·7 0·5 0·3

Absorption meter mm. alum.	Filter mm. alum.	Chromo radiometer					
1·5		Sabouraud B	1·0	0·9	0·7	0·5	0·3
		Kienböck x	15	13	10·5	7·5	5
1·8	0·5	Sabouraud B	1·2	1·1	0·9	0·6	0·4
		Kienböck x	27	24	19	14	9
2·0	2·0	Sabouraud B	2·0	1·8	1·4	1·0	0·6
		Kienböck x	50	45	35	25	15
2·5	3·4	Sabouraud B	3·0	2·7	2·0	1·5	1·0
		Kienböck x	70	63	49	35	21

Tables Nos. 20–24 refer to the percentage of the surface intensity which will be available at various depths below the surface.

This depends on—

1. The quality of the radiation as given by
   a. The boundary wave length.
   b. The filter.
2. The size of window on the skin.
3. The depth below the surface of the object to be treated.
4. The anticathode-skin distance.

In table 20 we have the percentage of the surface intensity which is available at 10 cm. below the surface for various wave lengths and various filters, when a window 6 × 8 cm. and an anticathode-skin distance of 50 cm. are employed. The boundary wave lengths vary from 0·09 to 0·17 A.U., and the filters from 0·2 to 1·0 mm. of zinc—there being added a constant 2 mm. of aluminium. Thus, if our radiation has a boundary wave length of

0·13 A.U. and we use a filter of 0·5 mm. zinc + 2 mm. aluminium, the depth dose under the above condition is 28·3 per cent. We will call this D_1. If we have no spectrometer, we can determine D_1 with the help of Kienböck strips or an Ionto quantimeter by the method described on pages 53–56.

No. 20.

λo in A.U.	F = mm. Zn + 2 mm. Alum.								
	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
0·09	25·5	28·2	30·5	32·5	34·2	35·5	36·6	37·0	37·4
0·10	24·5	27·2	29·5	31·5	33·2	34·4	35·5	36·1	36·4
0·11	23·6	26·3	28·6	30·4	32·2	33·5	34·6	35·0	35·4
0·12	22·6	25·4	27·7	29·4	31·1	32·5	33·5	34·0	34·4
0·13	21·8	24·5	26·8	28·3	30·1	31·5	32·5	33·0	33·4
0·14	20·9	23·6	25·8	27·3	29·1	30·5	31·5	32·0	32·4
0·15	20·0	22·7	24·8	26·2	28·0	29·5	30·5	31·0	31·4
0·16	19·2	21·9	23·8	25·2	27·0	28·5	29·4	30·0	30·4
0·17	18·4	21·0	22·8	24·1	25·9	27·6	28·4	29·0	29·4

Table 21 gives the variation of the percentage of the surface intensity available at a depth when we vary the size of the window.

From table 20 or from our Kienböck or Ionto quantimeter experiment, we have found the percentage depth dose D_1 under the conditions mentioned above. In table 21 we find what this percentage becomes when the area of the window (E) is changed from $6 \times 8 = 48$ cm². to something else. Thus if $D_1 = 28$ per cent at 48 cm². window, it becomes 31·7 per cent when the window area is increased to 8×10 cm. = 80 cm². We call this new percentage D_2.

Tables 22, 23, 24 give the variation of the percentage depth dose, D_2, when the depth of the object (d) and the anticathode-skin distance are changed. D_2 is the depth dose at 50 cm. anticathode-skin distance and 10 cm. depth of object. Table 22 gives the values for anticathode-skin distance of 25 cm., table 23 for 30 cm., and table 24 for 40 cm. Each of these tables gives the variation for varying depth of object.

Thus, if our anticathode-skin distance becomes 25 cm. and the depth of object 7 cm., the percentage depth dose, D_2 (31·7 per cent), becomes (see table 22) 33 per cent. If, however, the anticathode-skin distance is 30 cm. and the depth of object 12 cm., the value of D_2 (31·7 per cent) becomes (see

No. 21.

E \ D_1	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	31%	32%	33%	34%	35%	36%	37%
20	9·3	10·2	10·9	11·6	12·4	13·2	14·0	15·0	16·0	17·1	18·0	19·3	20·6	21·5	22·6	23·6	24·7	25·7	26·8	27·9
30	12·9	13·8	14·6	15·5	16·7	18·8	19·8	20·5	21·3	22·1	23·0	24·2	25·5	26·6	27·5	29·3	30·3	31·8	33·0	34·8
40	16·1	17·0	17·9	18·8	19·8	20·8	21·9	22·7	24·0	25·1	25·9	26·9	28·0	29·2	30·3	31·3	32·4	33·5	34·5	36·5
50	18·0	19·0	20·0	21·0	22·0	23·0	24·0	25·0	26·0	27·0	28·0	29·0	30·0	31·0	32·0	33·0	34·0	35·0	36·0	37·0
60	20·0	20·9	21·8	22·7	23·7	24·6	25·5	26·5	27·5	28·5	29·5	30·5	31·4	32·4	33·3	34·2	35·0	36·0	37·1	38·1
70	21·1	22·1	23·0	24·0	24·9	25·8	26·7	27·7	28·7	29·7	30·6	31·6	32·5	33·5	34·2	35·2	36·0	37·1	38·0	39·0
80	22·3	23·2	24·2	25·2	26·2	26·9	28·0	28·9	30·0	30·9	31·7	32·7	33·6	34·5	35·2	36·2	37·2	38·2	39·0	39·7
90	23·0	24·0	25·0	26·0	26·9	27·7	28·8	29·7	30·7	31·7	32·7	33·3	34·4	35·3	36·1	37·1	38·3	39·0	39·6	40·4
100	23·9	24·9	25·8	26·8	27·5	28·5	29·6	30·5	31·4	32·5	33·7	34·0	35·2	36·2	37·1	38·0	39·0	39·8	40·2	41·2
110	24·3	25·3	26·2	27·4	28·2	29·2	30·1	31·1	32·2	33·2	34·3	34·8	36·0	37·0	38·0	38·7	39·6	40·4	41·0	42·1
120	24·7	25·7	26·7	28·0	29·0	30·0	30·7	31·7	33·0	34·0	34·9	35·7	36·8	37·8	38·8	39·5	40·2	41·0	41·8	43·0
130	25·5	26·5	27·5	28·5	29·5	30·5	31·3	32·3	33·5	34·5	35·5	36·2	37·2	38·2	39·0	40·0	40·8	41·5	42·4	43·5
140	26·4	27·4	28·4	29·0	30·0	31·0	32·0	33·0	34·0	35·1	36·0	36·8	37·6	38·5	39·2	40·6	41·5	42·0	43·1	44·0
150	26·6	27·7	28·6	29·3	30·2	31·2	32·3	33·4	34·4	35·3	36·3	37·0	37·8	38·7	39·5	40·9	41·6	42·3	43·4	44·3

No. 22.—Anticathode-Skin Distance FS=25 cm.

D_2 / d	10%	12%	14%	16%	18%	20%	22%	24%	26%	28%	30%	32%	34%	36%	38%	40%	42%	44%
1	72·4	73·8	75·1	76·1	76·4	76·7	77·1	77·9	80·7	81·3	82·1	82·8	83·5	84·5	85·0	85·7	85·9	86·2
2	58·4	60·2	61·4	62·1	63·4	64·1	65·0	65·9	66·9	68·0	68·8	69·7	70·7	71·8	72·5	73·5	74·8	75·7
3	46·3	47·6	48·6	50·0	50·5	51·6	51·9	52·9	54·3	55·3	56·6	57·6	58·8	60·0	60·9	62·1	63·5	64·4
4	36·4	38·4	39·5	40·7	41·0	42·1	43·1	44·4	45·8	47·0	48·2	49·7	50·7	51·8	53·1	53·6	56·0	57·4
5	29·2	30·6	32·1	33·3	34·1	35·1	36·1	37·4	38·9	39·3	39·4	39·9	41·3	42·6	43·8	46·5	49·2	51·0
6	22·9	24·6	25·8	27·0	28·3	30·6	32·0	33·5	34·0	34·4	36·6	37·0	38·4	39·6	40·9	42·7	43·6	45·6
7	17·5	19·8	20·8	22·2	23·0	24·4	25·8	27·2	28·8	30·1	31·5	33·0	34·5	35·9	37·3	38·6	39·9	41·1
8	13·8	15·2	16·7	18·2	19·1	20·6	22·3	23·6	25·4	26·6	28·2	29·4	31·0	32·4	33·9	35·0	37·7	38·9
9	10·1	11·9	13·1	14·6	15·7	17·3	18·9	20·3	21·9	23·4	24·7	26·2	27·7	29·2	30·5	31·9	33·5	34·8
10	7·3	8·8	10·3	11·7	13·2	14·6	16·0	17·5	19·1	20·6	22·0	23·4	25·0	26·4	28·0	29·3	30·8	32·2
11	5·3	7·1	8·1	9·0	11·0	12·2	13·6	15·1	16·7	18·0	18·9	20·3	21·8	23·3	24·8	26·2	28·9	30·2
12	3·6	5·3	6·2	7·2	8·9	10·2	11·5	12·9	14·6	16·0	17·5	19·1	20·6	22·1	23·6	24·9	26·8	28·5
13	2·5	3·7	4·3	5·6	7·4	8·2	10·0	11·2	13·1	14·5	16·0	18·1	19·6	21·0	22·6	23·9	25·4	26·7
14	1·1	2·7	3·0	4·3	6·4	7·2	8·6	10·0	11·7	13·2	14·5	16·6	19·0	20·3	21·2	22·5	24·6	25·9
15	0·7	1.8	2·5	3·6	5·4	6·2	7·3	8·6	10·5	11·8	13·4	14·8	16·4	18·0	19·4	20·8	23·8	25·0

No. 23.—Anticathode-Skin Distance FS=30 cm.

D_a / d	10%	12%	14%	16%	18%	20%	22%	24%	26%	28%	30%	32%	34%	36%	38%	40%	42%	44%
1	73·4	74·8	76·0	77·1	77·4	77·7	78·1	78·9	81·7	82·4	83·2	83·9	84·6	85·5	86·0	86·8	87·0	87·4
2	59·2	61·0	62·1	62·9	64·2	65·0	65·8	66·8	67·8	68·8	69·7	70·6	71·6	72·7	73·4	74·5	75·8	76·7
3	48·0	49·4	50·5	51·8	52·3	53·5	53·8	54·9	56·3	57·4	58·6	59·7	61·0	62·1	63·2	64·4	65·8	66·8
4	38·2	40·2	41·4	42·7	43·0	44·1	45·2	46·5	48·0	49·3	50·5	52·1	53·1	54·3	55·6	56·1	58·6	60·1
5	30·9	32·4	34·0	35·2	36·0	37·1	38·2	39·5	41·1	41·5	41·6	42·2	43·6	45·0	46·4	49·2	52·0	53·9
6	24·5	26·2	27·6	28·9	30·2	31·4	32·7	34·2	35·8	36·3	36·7	38·0	39·5	41·0	42·3	43·7	46·7	48·6
7	18·9	21·4	22·4	24·0	24·8	26·3	27·9	29·4	31·1	32·5	34·0	35·6	37·2	38·7	40·2	41·6	43·0	44·3
8	15·0	16·5	18·1	19·8	20·7	22·4	24·2	25·7	27·6	28·9	30·6	31·9	33·6	35·2	36·8	38·0	40·8	42·2
9	11·1	13·0	14·3	16·0	17·2	18·9	20·7	22·2	24·0	25·6	27·1	28·7	30·3	31·9	33·4	34·9	36·6	38·1
10	8·1	9·7	11·4	12·9	14·6	16·1	17·6	19·3	21·1	22·7	24·3	25·9	27·6	29·2	30·8	32·3	34·0	35·6
11	5·9	7·9	9·0	10·2	12·2	13·6	15·1	16·8	18·6	20·0	21·0	22·5	24·2	25·9	27·6	29·1	32·1	33·5
12	4·0	6·0	6·9	8·1	10·0	11·4	12·9	14·4	16·3	17·9	19·6	21·4	23·1	24·7	26·4	27·9	30·0	31·9
13	2·8	4·2	4·9	6·3	8·3	9·2	11·1	12·6	14·7	16·3	18·0	20·3	22·1	23·7	25·4	26·9	28·5	30·1
14	1·2	3·0	3·5	4·9	7·2	8·1	9·7	11·3	13·2	14·9	16·3	18·7	21·4	22·9	24·0	25·3	27·7	29·2
15	0·8	2·1	2·8	4·7	6·1	7·0	8·2	9·8	11·9	13·4	15·2	16·8	18·6	20·4	22·0	23·5	26·8	28·3

No. 24.—Anticathode-Skin Distance FS=40 cm.

d \ D_2	10%	12%	14%	16%	18%	20%	22%	24%	26%	28%	30%	32%	34%	36%	38%	40%	42%	44%
1	74·5	75·9	77·2	78·4	78·6	79·0	79·3	80·0	83·0	83·6	84·5	85·2	86·0	86·9	87·3	88·2	88·4	88·6
2	61·1	63·0	64·1	64·9	66·3	67·1	68·0	69·0	70·0	71·1	72·1	73·0	74·0	75·2	75·8	76·9	78·3	79·2
3	50·2	51·6	52·7	54·1	54·6	55·8	56·2	57·3	58·8	59·9	61·3	62·4	63·6	64·9	66·0	67·2	68·7	69·8
4	40·6	42·7	43·9	45·4	45·7	46·9	48·0	49·4	51·0	52·4	53·6	55·4	56·4	57·7	59·2	59·6	62·3	63·6
5	33·2	34·8	36·6	37·8	38·7	39·9	41·1	42·5	44·2	44·6	44·8	45·4	46·9	48·4	49·9	52·9	55·9	58·0
6	26·7	28·6	29·6	31·5	32·9	34·2	35·7	37·3	39·1	39·6	40·0	41·4	43·1	44·7	46·2	47·6	50·9	53·1
7	20·6	23·6	24·7	26·5	27·4	29·0	30·8	32·4	34·3	35·8	37·5	39·2	41·0	42·6	44·4	45·9	47·4	48·8
8	16·7	18·4	20·2	22·0	23·1	24·9	26·9	28·6	30·7	31·9	34·1	35·5	37·4	39·2	40·9	42·4	45·5	47·0
9	12·5	14·6	16·1	18·0	19·3	21·2	23·3	25·0	27·0	28·8	30·5	32·3	34·1	35·9	37·6	39·2	41·2	42·8
10	9·3	11·1	12·6	14·3	16·2	17·9	19·5	21·4	23·4	25·2	27·0	28·8	30·6	32·4	34·2	35·9	37·8	39·5
11	6·7	9·0	10·3	11·5	14·0	15·5	17·2	19·2	21·3	22·9	24·0	25·7	27·6	29·6	31·5	33·3	36·7	38·2
12	4·6	7·0	8·0	9·4	11·6	13·2	15·0	16·7	18·9	20·7	22·7	24·8	26·8	28·6	30·7	32·4	34·8	37·0
13	3·2	4·9	5·7	7·4	9·7	10·7	13·0	14·7	17·2	19·1	21·0	23·7	25·9	27·7	29·7	31·4	33·3	35·2
14	1·4	3·5	4·1	5·8	8·5	9·6	11·4	13·3	15·6	17·6	19·3	22·1	25·3	27·1	28·4	29·9	32·7	34·5
15	0·9	2.5	3.3	5·6	7·2	8·3	9·8	11·7	14·2	16·0	18·1	20·0	22·2	24·3	26·2	28·0	32·0	33·7

Table No. 25 shows the various percentages of the erythema dose which, according to Professors Seitz and Wintz, will produce sterilization of the ovaries, or the disappearance of various malignant growths, and other biological results. In the first column are given the percentages of the erythema dose, in the second column the sensibility of various organs compared with that of the skin :—

Erythema dose	100 per cent	1
Sterilization dose of the ovaries ..	35 ,,	2·5
Sarcoma dose	60 to 70 per cent	1·6—1·4
Carcinoma dose	100 to 110 per cent	1·0—0·9
Bowels are injured with	135 per cent	0·74
Muscles are injured with	180 ,,	0·55
Dose for treatment of tuberculous disease	50 ,,	2·0

TABLE No. 26 COMPARES APPROXIMATELY VARIOUS QUALIMETERS OR PENETROMETERS.

Description of the quality of the rays	Wave lengths in A.U.	Absorption meter		Benoist penetrometer	Wehnelt penetrometer	Equivalent spark point and plate
		Aluminium	Water			
		mm.	mm.			cm.
Soft	—	0·5	5·0	3	3–4	3–4
,, ...	—	0·6	6·0	4	4–5	4–6
Medium soft .	—	0·8	8·0	5	7	6–8
,, ,,	0·6	1·0	10·0	6	8	10–15
Medium hard ..	0·45	2·0	20·0	7	10	15–18
,, ,, ..	—	2·5	25·0	8	12	18–20
,, ,, ..	—	3·0	30·0	9	14	20–22
Hard	0·25	8·0	—	10	—	25
,, ...	—	12·0	—	11–12	—	30
Very hard ..	0·17	16·0	—	—	—	35
,, ,, ..	0·1	20·0	—	—	—	40

SPARK COIL

AND

INTERRUPTERLESS TRANSFORMER X-RAY UNITS.

SCHALL & SON,
(W. E. SCHALL, B.Sc. Lond., F. Inst., P.)

71 and 75, New Cavendish Street, London, W. 1,
and 74, Bath Street, Glasgow.

Telephones: LONDON—MAYFAIR, 1212; GLASGOW—DOUGLAS, 2328.
Telegraphic Addresses: "SCHALL, PHONE, LONDON"; "SCHALLRAY, GLASGOW."

Estimates for SPARK COIL and INTERRUPTERLESS TRANSFORMER X-RAY UNITS.

The relative advantages of spark coils and interrupterless transformers, with or without high-tension rectifier, have been dealt with on pages 21–24. In the following pages there are mentioned the various apparatus of both types which we manufacture.

SPARK COIL UNITS.

All the coils to be mentioned are provided with very thick iron cores, consisting of thin sheets of a special kind of soft iron with which greater magnetic intensities can be obtained than with ordinary iron. The number of turns on the primary and secondary coils, the capacity of the condensers and the construction of the interrupters have been so chosen that the intensity of the currents induced on breaking the primary circuit is **the greatest which has so far been obtained with any coils of similar size.** The maximum spark length which can be obtained from any one of these coils under oil is about 30 per cent more than the distance between the sparking pillars.

The currents induced on closing the primary circuit are so weak that valve tubes can be dispensed with for diagnostic purposes up to secondary currents of 15 M.A. For therapeutic exposures of deep-seated organs, requiring more than about 150,000 volts and exposures of half an hour or more, the insertion of some kind of valve or spark gap is desirable for the better protection of the tubes.

At the present time we make the following four sizes of spark coils, which we can supply either separately or built into the four units mentioned below.

No. 2502.—Distance between sparking pillars 18 cm. (7 in.).

This size is recommended for dental purposes, for examination of fractures, the heart, lungs, etc. It may be used for time exposures of any other part of the body and for minor therapeutic exposures such as epilation and the treatment of some skin diseases.

Price complete with condenser and base **£30 0 0**

No. 2505.—Distance between sparking pillars 35 cm. (14 in.).

This size is largely used for diagnostic exposures. With one accelerating screen, fully exposed negatives of heart and lungs can be obtained in less than one second.

In therapeutic work it can be used for all skin treatment, and even for the sterilization of the ovaries. In the latter case, currents of 2·2 M.A. may not be exceeded, and after each run of half an hour, the coils must be

allowed to cool for a similar period. Then another sitting of the same duration can be given, so that altogether it can be used for five to six hours every day. It is not suitable for the treatment of deep-seated malignant disease.

This coil will do about 80 per cent of the radiological work which is required nowadays.

Price complete with condenser and base £50 0 0

No. 2508.—Distance between sparking pillars 50 cm. (20 in.).

With this coil **all** therapeutic and diagnostic exposures can be carried out. The construction is such that tubes with an equivalent spark gap of 34 cm. can be used with currents of 2·5 to 3 M.A. for therapy and, in addition, good negatives can be obtained when very soft tubes and some 15 M.A. are employed in diagnosis.

It is the type and size of X-ray apparatus best suited for hospitals and specialists who wish to do all the work with the same apparatus. For therapeutic purposes exposures lasting up to two hours at a stretch can be given, and, after a rest of not less than one hour, it can be used for another exposure of similar duration.

Price complete with condenser and base £80 0 0

No. 2510.—Special coil for deep therapy—used in pairs.

Length of maximum possible spark 85 cm. (33 in.).

These coils are specially wound for very high tensions, in such a way that one end is at 150,000 volts above or below earth potential, whereas the other end is near the potential of the earth. They are used in pairs placed in series, and the total voltage developed is 300,000. They are intended for uninterrupted runs of 10 hours. The voltage which they produce exceeds that of the coil No. 2508 by about 50 000 volts, but the main difference lies in the fact that they require no period of rest for cooling after a two-hour run, as does the No. 2508. They are therefore a necessity for those hospitals or specialists who either practice the technique of very large doses during one sitting, lasting for several hours, or who have a large number of cases to deal with so that the apparatus is kept running all day.

In spite of the high voltages developed by these coils, they may be used for diagnostic work **provided that very soft tubes** are connected with them. The voltage will drop then sufficiently low, and produce currents of some 15 M.A.

Price **per pair** complete with special condenser and bases .. £170 0 0

Larger coils of this pattern, also arranged in series, and to work ***two*** *tubes* simultaneously, can be supplied. They require a separate room adjoining the X-ray treatment room in which to be mounted. Estimates for such special installations will be given on application.

For Interrupters, Switchgear, and other accessory apparatus, we refer readers to our detailed catalogues concerning these articles.

We recommend the mercury and gas turbine interrupters No. 2527, as the best for all round use and particularly for therapy. These interrupters have been improved during recent years, so that even with the heaviest use of 8 to 10 hours a day, the mercury does not now require cleaning more than once in two or three months. With moderate use, once a year is sufficient. The only attention which they require is that a tap of the gas supply with which they must be connected, be opened in the morning, and the gas which issues from the vessel be ignited till it burns with a luminous flame. The issuing tap is then turned off and the supply tap left on. The latter is turned off in the evening. The axle of the interrupter must be kept lubricated

If no gas supply is available, cylinders with compressed gas can be employed or else the interrupter No. 2526 can be substituted.

COMPLETE X-RAY UNITS WITH SPARK COILS.

No. 3801, *consisting of* :—

No. 2502 or No. 2505 Spark Coil.

No. 2524 or No. 2527 Interrupter.

Trolley on which are mounted the lead glass window and switchboard with motor control, primary control, ampèremeter, switches and fuses.

Milliampèremeter.

No. 2612 tube stand and box as shown in illustration No. 3801.

Size of trolley, 37 in. long, 18 in. broad, 48 in. high to top of switchboard, 72 in. to top of tube stand.

This unit when fitted with the coil No. 2502 and the interrupter No. 2524 is capable of diagnostic work, and is then intended chiefly for dentists, general practitioners, and small cottage hospitals.

When it is fitted with coil No. 2505 and interrupter No. 2527, it is capable of diagnostic work and a considerable amount of therapy, including skin therapy and the sterilization of the ovaries by medium doses.

Its current consumption is under five ampères, so that it can be worked from a lamp socket.

For output, see page 153.

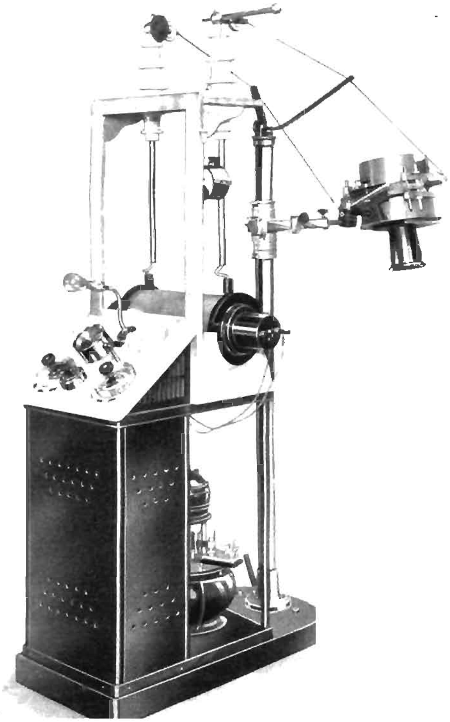
Its castors are strong and run easily so that it can readily be wheeled about the wards of a hospital.

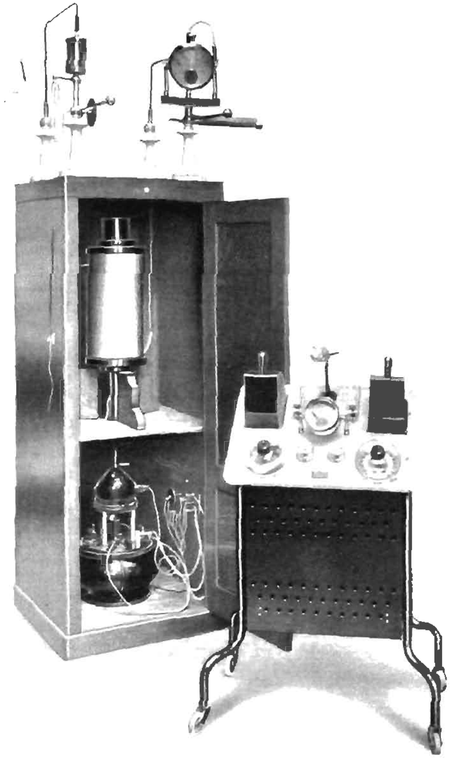
It must be operated from continuous current.

Price complete as described, with Coil No. 2502 and Interrupter No. 2524 .. .. **£120 0 0**

With Coil No. 2505 and Interrupter No. 2527 .. .. **£155 0 0**

The unit is so built that if the doctor wishes to increase its output at a later date by exchanging the coil and interrupter No. 2502 and 2524 for the larger size No. 2505 and No. 2527, we can make the exchange easily on payment of the difference in cost of the two parts, which amounts to about **£35.**





No. 3869.

No. 3869, consisting of :—

No. 2505 Spark Coil.	No. 2711 Spintermeter.
„ 2526 or 2527 Interrupter.	„ 2724 Milliampèremeter.
„ 2676 *Switch Trolley.*	„ *2609* Oscilloscope Tube.
„ 3869 Dark Oak Cabinet.	„ 2600 Rectifying Spark Gap.

As shown in illustration No. 3869.

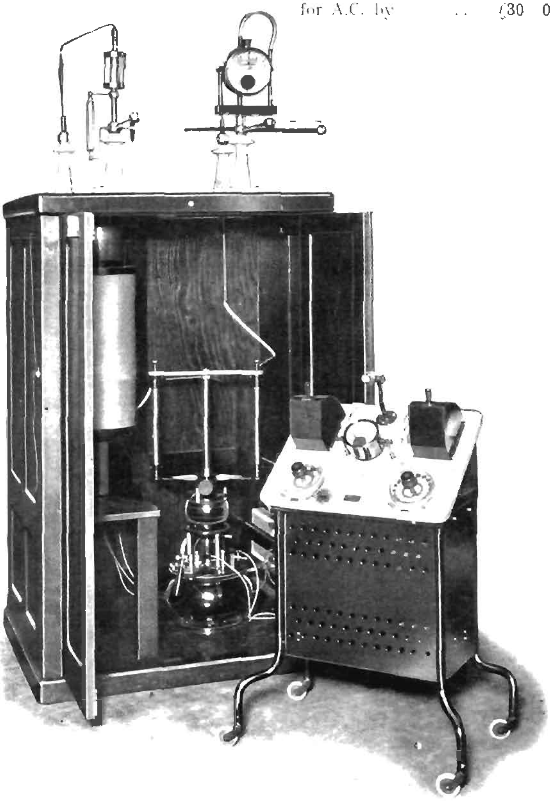
Size of cabinet, 24 in. deep, 24 in. broad, *86 in. high to top of M.A.* meter.

This unit is useful for all round radiology and for skin therapy.

It can be successfully used for sterilization of the ovaries by medium doses. The current consumption is under ten ampères on 200 volts.

For output, see page 153.

Price complete as described, for continuous current ..	..	£185 0 0
For alternating current (40 to 60 periods) ..	..	£220 0 0
The additions necessary to work Coolidge tubes increase the above prices for D.C. by	.	£50 0 0
for A.C. by	..	£30 0 0



No. 3870.

No. 3870, consisting of :—

No. 2508 Spark Coil.
,, 2527 Interrupter.
High-tension Rectifier for same.
No. 2676 Trolley Switchboard.
No. 2711 Spintermeter.
,, 2724 Milliampèremeter.
,, 2609 Oscilloscope Tube.
,, 2603 Rectifying Spark Gap.

Size of cabinet, 31 in. deep, 40 in. broad, 86 in. high to top of meter.

This unit is suitable for rapid diagnostic work and for all therapeutic exposures not exceeding two hours at a stretch.

Of all units which we make, this has the widest range of applications.

The current consumption is about ten ampères on 200 volts.

For output, see page 153.

Price complete as described for continuous current	£215 0 0
Price complete as described for alternating (40 to 60 periods) current	£240 0 0
The additions necessary to work a Coolidge tube increase the price for A.C. by	£30 0 0
for D.C. by	£50 0 0
A time release switch and clock for pre-arranged duration of exposures from 0·1 up to ten seconds can be added to the switch trolley for	£20 0 0
A speedometer can be added to control speed of the interrupter in therapeutic work for	£10 0 0

No. 3875, *consisting of* :—

- 2 No. 2510 Spark Coils.
- 1 No. 2527 Interrupter.
- Speedometer for same.
- No. 2676 Switch Trolley, with coarse and fine primary control, primary kilo voltmeter, ampèremeter, switches, fuses.
- Special Condenser.
- No. 3875 Dark Oak Cabinet.
- Sphere Gap Kilo Voltmeter.
- 2 No. 2601 Gas-filled Spark Gaps.
- 2 ,, 2602 Water Resistances.
- 2 ,, 2724 Milliampèremeter.
- 2 ,, 2609 Oscilloscope Tube.
- As shown in illustration No. 3875.

Size of cabinet, 36 in. deep, 57 in. broad, 87 in. high to top of spark gaps.

This unit is intended primarily to supply the hardest rays available from X-ray apparatus for continuous running up to ten hours at a time. It is essential for those specialists and hospitals who either apply single large doses at one sitting or who have so many cases to deal with that the apparatus is kept running all day. With very soft tubes, the apparatus can also be used for diagnostic work.

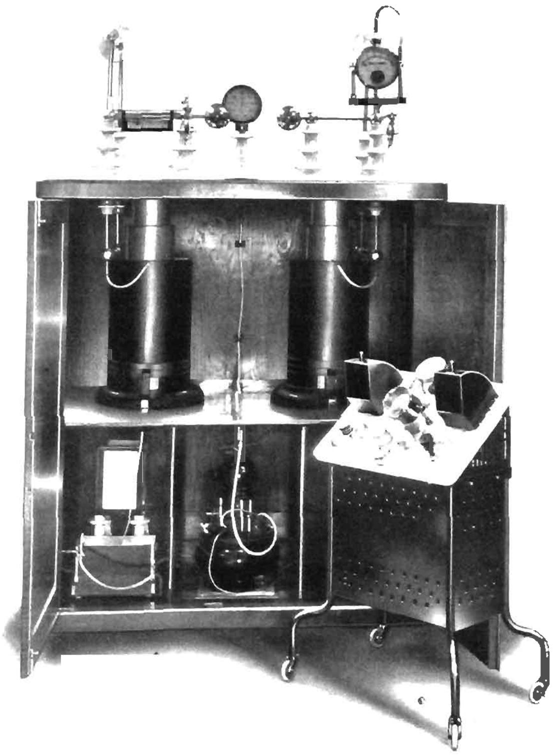
The current consumption is under ten ampères at 200 volts.

The actual output of the coils is given under No. 2510, page 153.

Price complete as described, for continuous current	£450 0 0
Price complete as described, for alternating (40 to 60 periods) current	£500 0 0

When boiling water gas tubes are used there can be added an automatic gas control for the regeneration, costing .. £35 0 0

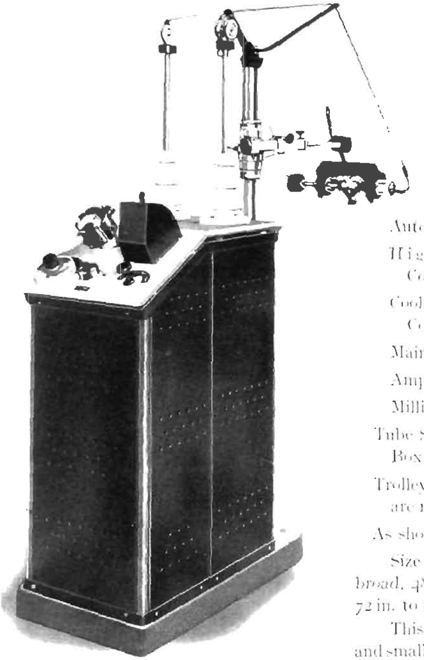
When 200 K.V. Coolidge tubes are used there must be added the Coolidge filament control, costing .. . £55 0 0



No. 3875.

Estimates and plans for installations of two coils, large enough to work two tubes simultaneously, with plans of the rooms for the electric apparatus and for the exposure of patients, will be supplied on application.

COMPLETE UNIT WITH INTERRUPTERLESS TRANSFORMER WITHOUT RECTIFIER ON TROLLEY.



No. 3900.

No. 3900, consisting of:—

- 5 K.V.A. High-tension Transformer.
- Auto Transformer.
- Switchboard, on which are mounted—
  - Auto Transformer Control.
  - High-tension Transformer Control.
  - Coolidge Heating Filament Control.
  - Main Switch.
  - Ampèremeter.
  - Milliampèremeter.
- Tube Stand with Protective Tube Box for Coolidge Tube.
- Trolley on which all the above are mounted, with large castors.

As shown in illustration No. 3900.

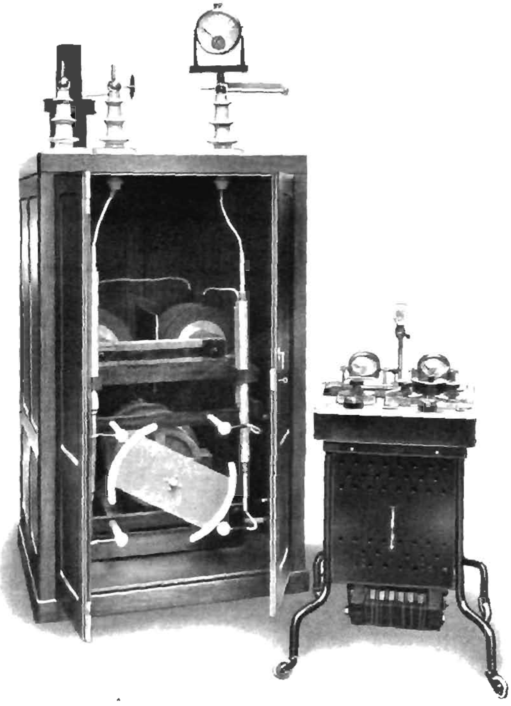
Size of trolley, 37 in. long, 18 in. broad, 48 in. to top of switchboard, 72 in. to top of tube stand.

This unit is intended for dentists and small hospitals for diagnostic exposures. It generates up to 30 M.A. through the radiator type Coolidge tube. It should not be employed for therapy because the heating of the anticathode of the Coolidge tube occurs after a few minutes' running, and then the current can pass in both directions through the tube to the detriment of the latter (see page 24). This unit cannot be used with gas tubes.

If a continuous current only is available, a rotary converter must be added to change this to an alternating current.

Price complete as described (but without Coolidge tube), for alternating current	£125 0 0
Price complete as described, with rotary converter for continuous current	£175 0 0

COMPLETE X-RAY UNIT WITH TRANSFORMER AND HIGH-TENSION RECTIFIER.



No. 3950.

No. 3950, consisting of :—

High-tension Transformer.
High-tension Rectifier.
10 K.V.A. Rotary Converter or Synchronous Motor.
Switch Trolley, on which are mounted—
  Auto Transformer Control.
  High-tension Transformer Control.
  Coolidge Heating Current Control.

No. 3950—*Continued.*

Time Clock for pre-arranged exposures up to 10 seconds.

Ampèremeter and Coolidge Filament Ampèremeter.

Phase Indicator and Reverser (if main supply is alternating).

Milliampèremeter. Dark Oak Cabinet.

As shown in illustration No. 3950.

Size of cabinet, 40 in. deep, 40 in. broad, 80 in. high to top of M. A. meter.

This unit is essentially for rapid radiography. It can be used for skin therapy, but is not as suitable for deep therapy as a spark coil. Output is given below.

An interrupterless transformer and rectifier, for deep therapy, can be supplied, but a high-tension transformer giving a peak voltage of 200,000 volts is a very large apparatus, which has to be installed in a separate room along with its rectifier.

Estimates for such plants will be given on application.

The current consumption is up to 50 ampères on 200 volts.

It must be borne in mind that the value of the milliampères obtained with these transformers is only one-half to one-third of the value in useful X rays of the milliampères obtained with coils. (See also pages 21–24.)

Price complete as described, for continuous current.. .. £400 0 0

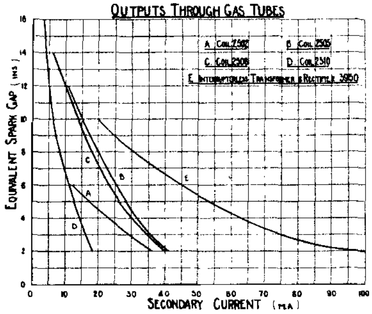
Price complete as described, for alternating (40 to 60 periods) current £350 0 0

OUTPUTS OF THE ABOVE UNITS THROUGH X-RAY TUBES.

Equivalent spark gap		Kilo volts on tube terminals	Boundary wave length Å	Current in Milliampères with						
				7 in. coil No. 2502	11 in. coil No. 2505		20 in. coil No. 2508		Deep therapy coils No. 2510	Interrupterless transformer and rectifier No. 3950
Inches	Cm.			Gas tube	Gas tube	Coolidge	Gas tube	Coolidge	Gas tube	Gas tube
2	5	30	0.41	36	41	105	40	90	18	100
4	10	50	0.25	23	32	95	31	80	14	63
6	15	70	0.18	12	25	85	23	68	11	45
8	20	92	0.13	—	20	72	18	60	8	30
10	25	110	0.11	—	15	55	14	55	6	20
12	30	128	0.09	—	10	30	10	50	5	—
14	35	142	0.08	—	—	—	6½	32	4	—
16	40	160	0.07	—	—	—	2	—	3	—

In reading the above figures one must bear in mind that the current generated by a coil produces between two and three times as much X-ray intensity as that generated by an interrupterless transformer.

And moreover, the gas tubes produce about 2·4 times as much X-ray intensity as Coolidge tubes, working at the same current and the same equivalent spark gap.



Any one of the units mentioned above must be completed by the addition of some accessories, tubes, tube stands, couches, etc., for which we refer the reader to our general catalogue and to our various other publications which will be sent on application.

In order to give an idea of the additional cost involved, we add a list of the most frequently required accessories for both diagnostic and therapeutic work. It should be noted that for the units 3801 and 3900 a tube stand is unnecessary because it is included in the unit. Furthermore, the nnit 3900 will work with Coolidge tubes only, whereas with all the other units either Coolidge or gas tubes may be used.

The cost of *one* Coolidge tube equals that of *four* heavy type gas tubes, and their lifetime is not longer than that of a gas tube. Unit No. 3875 operates with either the deep therapy Coolidge tube or with boiling water gas tubes, and the cost of one of the former equals that of two of the latter.

No.	2553AT.	Leviathan gas tube, *8 in. bulb*	£10	0	0
,,	2570.	Rib cooled ,, ,, ...	15	0	0
,,	2585AT.	Boiling water tube for deep therapy, seasoned and tested and furnished with details as to depth dose	40	0	0
,,	2591.	Coolidge tube, standard type, 7 in. diameter ..	40	0	0
,,	2592.	,, ,, radiator type, 3 in. diameter ..	40	0	0
,,	2593.	,, ,, dental type	40	0	0
,,	2594.	,, ,, deep therapy type	80	0	0

No. 2612.	Light metal tube stand with protective box ..	£25	0	0
,, 2616.	Heavy metal tube stand with protective box ..	55	0	0
,, 2618.	Ditto, for deep therapy	60	0	0
,, 2619.	Screening stand with tube box, certified by N.P.L. up to 100,000 volts, complete with fluorescent screen and plate holder	120	0	0
,, 2620.	Orthoscope screening stand and couch combined, complete with fluorescent screen and plate holder, and fitted with tube box certified by N.P.L. up to 100,000 volts	170	0	0
,, 2650.	Plain couch	8	0	0
,, 2653.	Couch with underslung tube box certified by N.P.L. up to 100,000 volts	85	0	0
,, 2653a.	Ditto, with over couch tube box and compressor ..	130	0	0
,, 2737.	Spectrometer for boundary wave length determinations of quality of the X-ray beam	30	0	0
,, 2739.	Absorption meter to determine the quality of the X-ray beam in terms of the thickness of aluminium necessary to reduce the intensity to one-half ..	2	0	0
,, 2752.	Kienböck quantimeter	2	10	0
,, 2752a.	Strips for same, in boxes of 50	0	10	6
,, 2754.	Ionto Quantimeter	50	0	0
,, 2805.	Fluorescent screens, 8 in. × 10 in., with lead glass	3	16	0
,, 2806.	Ditto 10 in. × 12. in.	6	0	0
,, 2807.	Ditto 12 in. × 15 in.	10	10	0
,, 2822.	Intensifying screen, 6½ in. × 8½ in. ..	1	10	0
,, 2823.	Ditto 8 in. × 10 in.	2	0	0
,, 2824.	Ditto 10 in. × 12 in.	2	10	0
,, 2825.	Ditto 12 in. × 15 in.	3	15	0
,, 3616.	Plate or film holder of aluminium, 6½ in. × 8½ in.	2	5	0
,, 3617.	Ditto ditto 8 in. × 10 in.	2	10	0
,, 3618.	Ditto ditto 10 in. × 12 in.	2	15	0
,, 3620.	Ditto ditto 12 in. × 15 in.	3	0	0
,, 3660.	Viewing box for plates up to 12 in. × 15 in. ..	10	0	0
,, 3670.	Wheatstone stereoscope	25	0	0
,, 3760.	Protective screen lined with 4 mm. lead and fitted with window of plate lead glass 20 mm. thick ..	25	0	0
,, 3761.	Ditto, with one wing	37	0	0
,, 3765.	Ditto, with two wings	50	0	0

GUARANTEE.

We guarantee our spark coils and transformers and all other apparatus which we manufacture against breakdown due to faulty workmanship or material, for a period of two years from date of delivery. This means that any defects arising from the two causes mentioned above will be repaired or the faulty parts replaced free of charge. In any case of breakdown we will endeavour by the loan of apparatus, to prevent a discontinuity of work, but the above guarantee does not make us responsible for consequential damages.

As to the durability of our apparatus, we would like to mention that we supplied a spark coil No. 2505, with interrupter No. 2524, and two X-ray tubes No. 2542, to Dr. Westmacott of Manchester soon after the outbreak of the war. The unit was transferred to the 2nd Western General Hospital, where it produced forty thousand negatives and nearly as many screen examinations **without a single repair or renewal** becoming necessary. At present the unit is still in actual use in Manchester.

In our catalogue of 1922 will be found as references the addresses of some hundred hospitals and medical men using our X-ray apparatus, and some of the unsolicited testimonials received.

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